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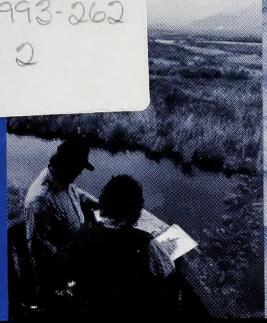

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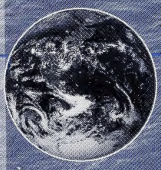

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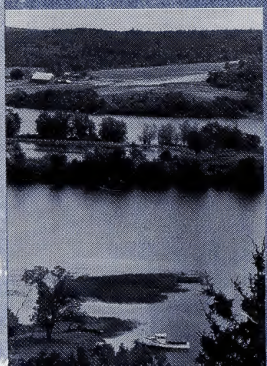

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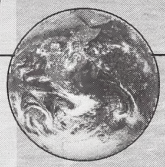

Stephen K. Evans

ACCESS NETWORK

With funding provided by
Ecosystem Sciences and Evaluation Directorate, Conservation and Protection Service

Environment Canada | Environnement Canada

Environmental Citizenship
Écocivisme

Readings—The Living Flow was written by Stephen K. Evans. Hour overviews and essay descriptions were written by Bruce Murphy. Publication was made possible by funding provided from the Ecosystem Sciences and Evaluation Directorate, Conservation and Protection Service, Environment Canada.

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The program order numbers and titles are:

BPN 3530-01 Hour One—*Myth, Reality, Bridge*
BPN 3530-02 Hour Two—*Flow, Tides, Symphony*
BPN 3530-03 Hour Three—*LAW, Impacts, DAM!*
BPN 3530-04 Hour Four—*Zero, Choices, Responsibility*

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FAX: (403) 256-6837

Out-of-province orders or inquiries about this program and this publication should be addressed to ACCESS NETWORK Program Sales, at the above address.

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ISBN 1-895350-06-9

Printed and Bound in Canada

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Printed on Recyled Paper.
Cover: Oxygen Bleached
Text: Non-chlorine Bleached

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Acknowledgements

Funding Organizations and Agencies

Funding for the production of **The Living Flow** was provided by the following agencies. Without their patient support, this project would not exist.

The Donner Canadian Foundation

Canadian Studies Directorate
Secretary of State

Science Culture Canada
Supply and Services Canada

Energy Mines and Resources Canada

Agriculture Canada

Ecosystem Sciences and
Evaluation Directorate
Environment Canada
(formerly Inland Waters Directorate)

Alberta Recreation Parks & Wildlife Foundation

Project Reviewers

Grateful acknowledgement is made of the advice and comment provided by the following during development of **The Living Flow**. The completed project does not necessarily reflect their views.

Don Gamble
Rawson Academy of Aquatic Science

Ralph Pentland
Ecosystem Sciences and Evaluation Directorate (formerly Inland Waters Directorate)

Dr. Steve Hrudey
University of Alberta

William Smith
Science Council of Canada

Dr. Bruce Mitchell
University of Waterloo

Gary Webster
Canadian Petroleum Association

Archie Landals
Environment Council of Alberta

Ross Hicks
Energy, Mines & Resources Canada

Dr. Rowland Lorimer
Simon Fraser University

Our sincerest appreciation to the following and their organizations for their input and advice during the early development of this project.

Stephan Bodsworth
Fairview College

Dr. David Chanasyk
University of Alberta

Roger Dion
Red Deer College

Clarence Esau
Big Country Educational Consortia

Rik Hall
Fairview College

Ed Harding
Westerra Institute of Technology

Robert Lockwood
Olds College

Howard Mayer
Grande Prairie Regional College

Brian Meller
Lethbridge Community College

Griff Richards
Westerra Institute of Technology

Introduction

To the Learner:

The Living Flow is a telecourse about water and its importance to all forms of life, and about the increasingly difficult choices society will have to make for its use and management in the future.

In the past, water has not only been perceived as an unlimited 'resource', capable of supporting unfettered growth, but it has also been seen in isolation—compartmentalized to the immediate use or need in question. The telecourse presents a vision of water that is more complex and, we think, more integrated. Water is a finite resource which does not exist in isolation from the biophysical environment and the range of human needs it can serve. It is inextricably linked to land and air, to the survival of all plants and animals, to human history, to the development of society, and to the aspirations of future generations.

These linkages define what we refer to as water's *interconnectedness*, the underlying theme of **The Living Flow**. This theme unfolds as the telecourse probes water's properties and the reasons water has been called the 'lifeblood' of the environment, and is continually reiterated in our discussion of water-related issues in Canada, where the use and management of water for one purpose often conflicts with that of another. And it is exemplified in our analysis of choices, in which we show that the costs and benefits associated with water are often tempered by political and technological considerations.

Above all, **The Living Flow** seeks to raise awareness of water-related issues and to promote a sense of personal, societal and global responsibility for the use and management of water. We realize that the subject of water is exceedingly complex, and so we have chosen to present challenges rather than solutions. We invite you, the participants, to review the evidence and draw your own conclusions. To do so, you will need to know more about water, its properties, its role in the biosphere, and the present and future possibilities for using and managing it—all important information upon which to base your decisions.

The telecourse has been designed as a learning resource for those enrolled in post-secondary institutions where water and water management are related topics of study. We believe that the telecourse will support an interdisciplinary study of water and water management in your particular program, and that as future water scientists and decision-makers, you will benefit from the integrated manner in which we have approached the subject.

Telecourse Structure

The Television Series

The television series consists of four one-hour programs. Each hour describes water's interconnectedness from different major perspectives. **Hour One** looks at the origins of societal beliefs and values about water and the environment. Water's role in ecosystems is presented in **Hour Two**, and the management of water in **Hour Three**. **Hour Four** summarizes the series and explores options for the future.

Each of the hours has five parts: an *opening*, three *essays*, and a *closing*. The essays are thematic and cover one or more specific water-related concepts. In addition, the essays present issues and problems in a regional context. Individual essays within an hour are connected to the program's overall focus; each, however, is self-contained and can stand alone.

The television series is particularly valuable in visualizing water management issues as they are unfolding across Canada. You will see first-hand the work underway in Dauphin, Manitoba, to rehabilitate streams damaged by flood control and farm drainage, and the bid by citizens of Sudbury, Ontario, to bring its infamous moonscape back to life. You will witness the efforts of businessmen to adopt environmentally-sound production practices. Placing these concrete examples in context are interviews with authoritative commentators in the fields of ecology, public health and water management.

Readings—The Living Flow

Readings—The Living Flow is a companion print resource intended for students enrolled in post-secondary programs where water and water management are part of the curriculum. You will find that this book has been organized into four units, one corresponding to each of the television hours. Each unit contains a *focus statement, unit objectives, key concepts,* an *overview* of the complete television hour, *essay descriptions, studies* (readings on a particular aspect of water), *discussion questions*, and *recommended readings*. Resources, the final section, provides a *list of independent study options*, a *glossary of terms*, *common measurements and metric conversion table*, a *selected bibliography* and an *index*.

The studies are intended to supplement and expand upon the content of the telecourse. Each study presents specific concepts related to water, such as flow variation, assimilative capacity, water use, sewage treatment technology and demand management. Many of the studies also contain case studies, which draw from the literature on water management and explore water-related issues in a regional context. Water Shortages on the Prairies, for instance, reviews western settlement and irrigation development as a prelude to examining the controversy over construction of the Oldman Dam in southern Alberta.

In addition to the basic information on water use and management, the telecourse highlights global concepts and themes which weave in and out as they are developed, left, then re-examined in a different context. The telecourse requires your active involvement in linking these ideas and in discovering the subtle interconnections of The Living Flow. To assist you, unit objectives, key concepts and discussion questions are provided. The unit objectives cover content and terms required for an understanding of water use and management. The key concepts identify major themes related to the broader political, social, ecological, economic and technological aspects of water management. The discussion questions ask you to synthesize and evaluate your learning, and to reflect on your own behaviours, values and attitudes about water, the environment and the need for change.

Telecourse Utilization

The Telecourse as a Classroom Learning Activity

In this option, the television and print components are used as the basis for class discussion. Your instructor will likely want you to view the television components in a learning resource centre or library prior to the class, but may elect to show complete hours or individual essays to the class as a whole. We recommend you read the hour overviews, essay descriptions and unit studies before watching the television program.

In preparing for the class discussion, it will be useful for you to have a working knowledge of terms presented in both the television component and in the readings. The glossary in *Readings* is a handy reference for reviewing terms. We also suggest you read the discussion questions prior to class, and put your thoughts down on paper.

The Telecourse as Self-Directed Study

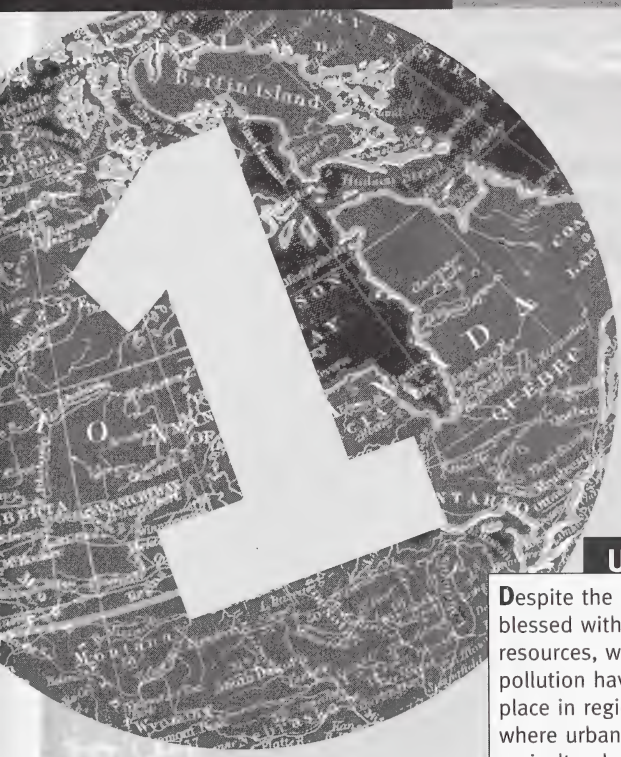
In this option, the television and print components are the basis for independent study. As before, we suggest that you read the hour overviews and essay descriptions before viewing the television components; as there is no class discussion, you have the option of reading the studies before or after viewing. We strongly recommend that the units be done in sequence.

Once you have completed the unit, go back over the unit objectives and key concepts to test your understanding of important definitions and concepts. If you have difficulty, refer to the glossary or review the studies and television essays.

The self-directed study option will likely require the completion of assignments related to the telecourse. You may wish to prepare written responses to the discussion questions for each unit, or you may want to do one or more of the

research options described at the end of *Readings*. Your choice should be made in consultation with your instructor.

UNIT



Unit Focus

Despite the fact that Canada is blessed with abundant water resources, water shortages and pollution have become commonplace in regions of the country where urban, industrial and agricultural development has been intensive. This reality forces us to examine the myths we hold about nature, about water and about economic growth and development as the sole measure of human progress. In the long term, our use of natural resources like water must be sustainable if our children are to enjoy a standard of living comparable to ours.

Unit Objectives

At the conclusion of the unit, you should be able to:

1. identify factors which contribute to *streamflow* variation
2. differentiate between *natural, recorded, renewable* and *reliable flows*
3. identify factors which influence *water quality*
4. explain the interrelationship between water quality and quantity
5. distinguish between *point* and *non-point* sources of pollution
6. explain the *myth of superabundance*
7. differentiate between *sustainability* and *sustainable development.*

Key Concepts

At the conclusion of the unit, you should understand that:

1. water is essential to all forms of life
2. water provides the means for economic growth and development
3. Canada, compared with most other countries, is well endowed with water
4. the availability of water is affected by geographic and temporal factors
5. regional variation in supply and population demographics has led to locally-occurring shortages and pollution
6. natural supply patterns cannot keep pace with our demand for fresh water
7. growing pressures on the resource serve to illustrate that Canadians can no longer take their water supplies for granted
8. *sustainable development* requires the integration of development and environmental decision-making.

Hour One Overview

There are points where myth and reality intersect—the nightly news, the paper we read each morning, the discussions we hold with friends and colleagues.

Prominently featured in all three are the problems that have led some commentators to call the 1990s the 'Turnaround Decade' for the global environment: ozone depletion, acid rain, the Greenhouse Effect, desertification, toxic contamination. All of these problems are, in one way or another, related to water, and their reality is embedded in the three essays of **The Living Flow's** first hour.

But every reality is also shaped by our myths...the dreams, fears, hopes and values with which Canadians relate to their environment. And these myths are often contradictory...simultaneously perceived and acted on as separateness or partnership, as exploitation or protection, as domination or stewardship.

The essay **MYTH** explores the beliefs and attitudes that have dominated the development of Canadian society: in particular, the perception that Canada is blessed with abundant, even unlimited, supplies of water. **REALITY** describes the legacy left by two centuries of rapid growth and development: water shortages and water pollution in some regions of Canada, and widespread destruction of aquatic habitat. The lesson? There is a need for myths more appropriate to a finite and fragile world. **BRIDGE** examines the development of environmentalism from its roots in the late 19th century to the environmental conflicts of the last few decades. The concept of sustainable development, the most recent attempt at redefining the human relationship with the natural world and reversing human impacts to the ecosystem, provides a yardstick with which to evaluate water use and management practices in the succeeding hours of the series.

MYTH – Essay Description

"But, admiring these pastoral scenes, we forget that colonizing Canada was as relentless and as destructive of ecosystems as the clearing of the Amazon jungle modern Canadians criticize and fear."

Drive or fly across northern Canada and the dominant impression is of an ageless landscape. While the rocks that buttress and define a seemingly unending patchwork of lakes and rivers are among the oldest in the world, life here is young in geological terms. As little as ten thousand years ago, most of Canada lay under sheets of ice and on their fringes the first Canadians huddled by campfires.

Imagine, as the ice retreated, these people following it into the newly-bare land and witnessing what must have seemed a miracle—the creation, the unfolding of a life-filled world in which humans were not separate but part and parcel. From a perspective so close to nature, they spoke of this web with awe and reverence in their myths and campfire tales.

There was no such reverence in European myths. To these newcomers, nature was an enemy, to be 'tamed', 'subdued', 'defeated'. They very nearly succeeded. Natives, wildlife and ecosystems were treated alike, plundered with little thought or understanding. And so was water, seemingly the most superabundant resource in a land of boundless opportunity. Rivers were 'harnessed' for economic growth, their shorelines denuded and their waters filled with sediments. Sewage dumped into lakes caused epidemics of typhoid and cholera but, rather than curb the pollution, drinking water was chlorinated—an early example of a pattern now called *react and cure*.

Over time, controlling water to protect against drought, generate electricity and supply towns and industries became part of our national myth-making. Dams came to symbolize progress itself and politicians strutted the stage at their openings. In fact, when it comes to dams, few countries outbuild Canada, and not one moves more water. Canada transfers more water between river systems than the combined totals of our two nearest rivals, the United States and the former Soviet Union.

Along the way, Canadians became the second-largest per capita users of water in the world, a fitting statistic given that Canadians are world leaders in the production of garbage and use of energy and natural resources. Much of the world envies the lifestyle fostered by this extravagance, but there is no free lunch or, in this case, free glass of water. The notion that there is an unending supply of fresh water has turned out to be a myth. Even a hundred years ago, it was apparent that our water resources were showing signs of stress. Now, reality is setting in.

REALITY – Essay Description

"It's a song from another era, from a time when the winds and the oceans seemed the unchanging backdrops to life.

"But the winds have changed. The oceans have changed. And so have Canadians."

Framed against a backdrop of distant mountains, 8,000 people applaud the song 'Four Strong Winds', bringing to a close a day of music and protest against the construction of the Oldman River Dam in southern Alberta. But as television beamed news of the event across the country, there were many whose hands were still. Water use remains a central battleground in a war that seems to pit 'Jobs jobs jobs!' against the protection and preservation of the environment for the future—not an easy choice, and not necessarily a real one.

With water supply short to start with, progressive settlement of the grasslands has exacerbated the problem there. Demand for water already exceeds the *reliable supply* in several areas, even as demand continues to grow and climate change is projected to bring still drier conditions. Expansion of the region's security blanket—an already vast infrastructure of dams and irrigation canals—is limited both by the amount of water ultimately available and by strong opposition from environmental organizations.

In the Great Lakes, there is potential for similar supply problems. With more than 37 million Americans and Canadians crowded around their shores, the Lakes' *renewable supply* (less than one per cent of their total volume) is projected to be exceeded by *consumptive* uses in the next half-century. But the supply of high-quality water for drinking and recreation is already threatened. Beaches around Great Lakes cities are routinely closed because of sewage contamination. And fear of toxic contamination has created a boom in sales of bottled water and home-filtration systems.

While evidence of direct effects on human health remains limited, cancerous fish, deformed birds, and the continued death of belugas in the upper St. Lawrence River have convinced the International Joint Commission that toxics in the Great Lakes ecosystem do pose a threat to humans. Further, the now-disbanded Science Council of Canada has estimated that the health of one million Canadians is threatened by the presence of toxics in the groundwater on which they depend. To those numbers, add millions more at health or economic risk from the tightening circle of a mutated Living Flow—toxics transported thousands of miles on the winds, acids falling from the sky—and the question must be asked: is the human situation any different from that facing wildlife?

Unable to escape the crush of human development, wildlife survives in increasingly-isolated pockets such as the Fraser River delta outside Vancouver, a once-vast habitat now shrunk to just 30 per cent of its historic size. And what remains is threatened by further development and pollution. The same is true for humans. 'Jobs jobs jobs!' versus 'Protect the environment!' is a false choice. The question really is, how can they both be protected?

BRIDGE – Essay Description

"There's a story that, in one version, goes like this: a judge was hearing a case against a pulp mill accused of polluting the air. 'It smelt bad,' said the complainants. 'That,' sniffed the judge as he dismissed the case, 'is the smell of money.'"

For most of our history, pollution and environmental degradation have been accepted as the inevitable and acceptable consequences of prosperity. But this 'growth ethic' has not been unopposed. Canada's conservation movement can be said to have started in the 1880s, when Edgar Dewdney, Lieutenant-Governor of the then Northwest Territories, recommended that a few quarter sections at the north end of Saskatchewan's Last Mountain Lake be kept from development. By 1909, pollution problems were serious enough to warrant a clause in the Canada-U.S. *Boundary Waters Treaty*.

But it would be more than half a century before that clause was truly enforced. In the rush of change and events that mark the 20th century, conservation and pollution control were seeds planted largely on barren ground. It was not until the 1960s, when Rachel Carson's *Silent Spring* detailed the horrors of pesticide pollution, and the American space program showed the reality of Earth's lonely course through inhospitable space, that the price of progress was seriously questioned. Conservation and pollution control were wedded with preservation, and modern environmentalism was born.

At first, the message was confused with the messenger—the radical movements that convulsed both Canada and the United States in the late 1960s—and environmentalism was rejected as antithetical to progress. The movement's contention that there were limits to growth was also dismissed as naïve. Throughout the 1970s, environment and economy remained two solitudes.

But in the early 1980s, the toll of human development came to be summed up in the phrase 'global change', and the recognition grew that environment and economy were interdependent. The health of one depends on the health of the other and, to be sustainable, development must respect the integrity of natural

systems. Conversely, economic growth was necessary both to fund environmental protection and to deal with an exploding human population.

This rationale for *sustainable development* was expounded in *Our Common Future*, the report of the United Nations Commission on Environment and Development. In Canada, the concept's endorsement by the National Task Force on Environment and Economy (a multi-sectoral 'round table' that included ministers of the environment, businesspeople and environmentalists) was soon followed by the approval of the federal and every provincial government. A few small steps, and a giant leap of faith, had been taken across the environment-economy bridge.

Study One: About Water

Water is a colourless, odourless and tasteless substance which is abundant in the earth's crust and atmosphere. Chemically, water is composed of hydrogen and oxygen. Physically, it may exist as a liquid, solid or gas. These fairly mundane descriptions of water disguise its importance. If there was no water on earth, life as we know it would simply not exist.

Why is water so vital? Part of the answer lies in water's unique combination of properties. To begin with, water molecules tend to stick together and, by capillary action, are able to move up the stems of plants or down through the soil to plant roots. The same forces that bond water molecules together account for the fact that water expands on freezing, and so ice, which is less dense than water, forms on the surface of lakes rather than on the bottom. Furthermore, water absorbs or radiates a great deal of heat, a property that makes the oceans moderators of the earth's temperature. Finally, water is an excellent solvent and an ideal medium for transporting essential materials to, and through, living organisms. This property is particularly important to cells, which can only utilize subtances in dissolved form.

These same properties influence the way water interacts with the physical environment. Because water readily changes state, it is continually redistributed by the *hydrologic cycle*. As water moves over the surface of the land, it picks up and transports solutes and sediments into rivers, lakes and oceans. Water's composition, influenced by both of these processes, determines its suitability as habitat. In its broadest context, water is a fundamental component of the ecosystem.

Humans also depend on water. Two litres are required daily in liquid form or in the food we eat, and we will die if water loss exceeds ten per cent of our body weight. Beyond our physiological needs, water has an intrinsic value. Among primitive tribes, water was associated with fertility and even now, Inuit hunters return a portion of their catch to the sea to ensure its continued bounty. The aesthetic

qualities we attribute to water are reflected in the ballads, poetry and paintings of our artists. As Canadians, we take pride in our pristine lakes and streams, an image we deliberately present to visitors and tourists. So closely do we identify with our water resources that the idea of selling them arouses strong nationalistic feelings.

But beyond that, water is essential to our economic growth and development. Historically, human settlement occurred along rivers, lakes and coastlines, and water was essential to trade, agriculture and later to the development of energy and industry. Today, water figures in virtually every facet of our daily existence, but most of it is hidden from our view.

Apart from the 350 to 400 litres used in the average home each day, just producing the ingredients for a typical Western high-protein diet of 3000 calories per day takes more than a cubic metre of water, about ten bathtubs-full. Manufacturing the goods and producing the energy that have become an integral part of our lives uses prodigious amounts of water: about 570 litres to produce a typical weekend newspaper; ten litres to refine a litre of gasoline; roughly 250,000 litres of water to produce a tonne of steel. Water is also used extensively as an industrial coolant and in the extraction, processing and refining of minerals and petrochemicals. For such an important resource, it's a little surprising that its value is also hidden. Estimates for water's annual contribution to Canada's economy each year range between $8 and $23 billion. Our lifestyle, the envy of most of the world, is heavily based on water.

Economic activity, however, invariably leads to environmental stress, particularly with natural resources like water. We see this most clearly in the pollution of rivers, lakes and coastal waters by human and industrial wastes. Less obvious, perhaps, are human impacts on the air and land that affect water systems. Pollutants from smelters, coal-burning power plants and automobiles destroy aquatic life in thousands of lakes and rivers. Streams choked with sediments smother fish eggs in spawning grounds. Excessive amounts of nutrients contained in fertilizers accelerate the natural aging process in lakes. Pesticides gradually accumulate through the food chain, decreasing the fertility of predatory birds and mammals. In all of these instances, we are altering the physical and chemical properties of water systems to the extent that they can no longer support life.

It is not just that we require water for economic growth but that we require it in ever-greater amounts. In the long term, however, our demands for water will begin to outstrip the available supply. Since 1900, the population on Earth has tripled while the demand for water has increased seven-fold. The same mismatch between population growth and demand growth has occurred in Canada, and projections indicate demand for water in this country could double within a generation, given present trends in water use.

To understand how we have arrived at this point requires an examination of our beliefs and values about water as a resource. We have long perceived water to be a plentiful, even *superabundant resource*, capable of supporting unfettered growth. We have also considered water as a *free good* to which we have an inherent right. Thus, there has been little incentive to conserve and protect it, despite its obvious economic value. Finally, we have tended to see our own needs for water as somehow separate from the needs of other forms of life.

Some of these beliefs and values have origins in western concepts of religion, philosophy and science. The Book of Genesis, for example, presents Man as master of the earth, having dominion over all life. This belief prevailed during the European colonial period, when nature was considered to be wild and unpredictable, to be subdued in the name of human civilization. Scientific thought, as it evolved in western society, reasoned that natural phenomena could be understood by subjecting them to observation, experimentation and verification. Francis Bacon, an English philosopher and essayist, saw scientific knowledge as a means of commanding nature to action for the benefit of man. Comte and other 19th-century writers characterized science as the study of 'real' phenomena (those which could be measured empirically) and scientists as detached and objective observers.

These ideas define what might be called an *egocentric* view of our relationship with nature: that we are somehow separate from nature and that our science and technology can overcome whatever barriers nature might present. Egocentrism, still the dominant philosophy of our culture today, has reinforced an industrial philosophy that equates growth with progress, the generation of wealth and an overall improved standard of living, irrespective of the damage that might be caused to the environment.

Although our attitudes toward the environment are beginning to change, we still often believe that water management problems can be solved by engineering. A fascinating if frightening illustration of this attitude is the attempt by the U.S. Army Corps of Engineers to control the Mississippi River.

The Mississippi River: A Case Study

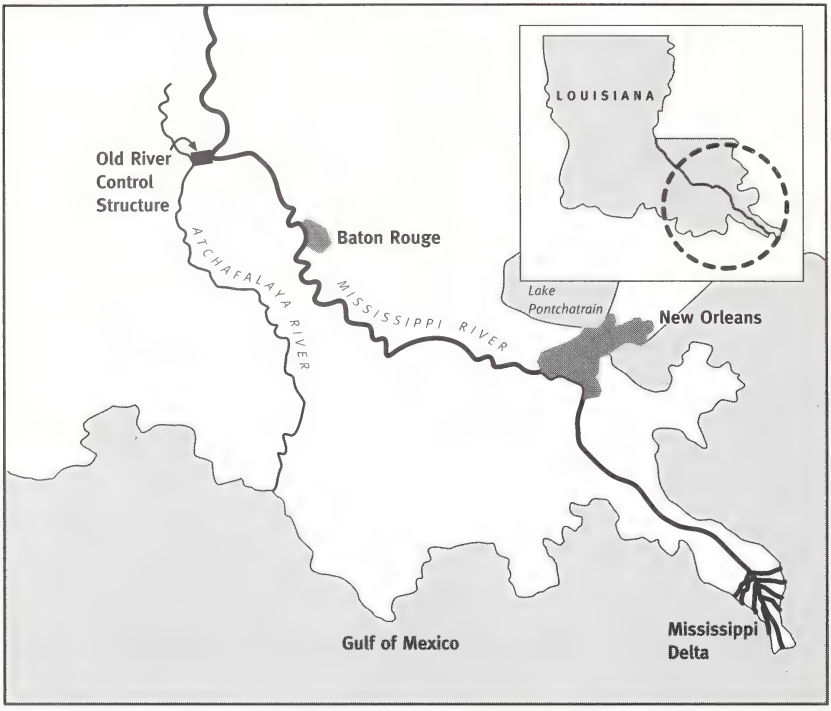


Figure 1: *Old River Control Structure–Built by the U.S. Army Corps of Engineers in the early 1950s to halt the capture of the Mississippi River by the Atchafalaya River, the Old River Control Structure protects the economic interests of an entire region.*

With its vast loads of sand and silt, the Mississippi River has created most of Louisiana, and could not have done so by remaining in one channel. Throughout its history, the river has changed course to accommodate the build-up of sediments in its bed. Because it is the river's purpose to get to the Gulf of Mexico by the shortest and steepest gradient, it can be captured when its meanders (or bends) approach adjacent watersheds. In each decade since 1860, the Atchafalaya River has drawn off more water from the Mississippi than the preceding one. By 1950, the Atchafalaya, via a former meander bend called Old River, was ready to receive the waters of the Mississippi, shortening the route of the master stream to the Gulf by almost 240 kilometres.

For the Mississippi to make such a change was completely natural, but in the interval since its last shift, a nation had developed along its banks and tributaries. And that nation could not afford nature. The consequences of the Atchafalaya's

capture would be the demise of Baton Rouge, New Orleans and a host of industries along the 'American Ruhr', including du Pont, B.F. Goodrich, Union Carbide, Monsanto and Dow Chemical.

Shortly after 1950, the U.S. Army Corps of Engineers was directed by the American Congress to construct what is technically called a sill, or weir, across the Old River channel. The structure, when completed, would be 172 metres long and contain eleven gates which could be raised or lowered, thus controlling flow from the Mississippi into the Atchafalaya. In a promotional film on the project, the Corps argued that the United States had a large and powerful adversary which could cause her to lose nearly all her seaborne commerce and her standing among trading nations. "We are fighting Mother Nature," the film said. "It's a battle we have to fight day by day, year by year. The health of our economy depends on victory."

There were some who doubted the wisdom of the Corps. Oliver Houek, a professor of law at Tulane University, characterized the enterprise as extreme arrogance. A study published by the Water Resources Insititute at Louisiana State University predicted that the structure would fail. "Just when this will occur cannot be predicted," the report concluded. "It could happen next year, during the next decade, or sometime in the next thirty or forty years. But the final outcome is simply a matter of time and it is only prudent to prepare for it."

After going on-line in 1963, the control structure at Old River had to wait a decade to prove what it could do. The first ten years were relatively quiet, but in the fall of 1972 and winter of 1973, river stages were higher than normal due to heavy snows in the upper watershed and heavy rains in the south. During the sustained spring high water, the combined drainage from Montana to New York came to Old River in volumes exceeding 50,000 m^3/second (the Mississippi's average annual flow is about 17,000 m^3/s). In March, the structure began to noticeably vibrate, and a large eddy from the swirling water started to excavate sediments upon which the structure was resting. On the outflow side, the release of water through the gates had carved out a hole the size of a football stadium in the Old River Channel. At the height of the flood, the guide walls, built on the inflow side to bring in the water, started slipping into the river.

After the floodwaters had receded, the Corps set about assessing the damage. The structure was obviously undermined, but to what extent? To find out, Corps engineers bored holes through the centre of the structure and lowered a television camera down to the bottom. What they saw were fish. The high flows had eaten away at the very foundation.

Although the Old River Control Structure survived the flood of 1973, there is no guarantee that it will again. The Mississippi River is bordered by levees, first constructed when New Orleans was built in 1718. Over the years, the levees have been raised to keep the river from flooding, and each time they have failed

because inadvertently they themselves cause the flood waters to rise. The Mississippi River and Tributaries Project, at a projected cost of $7 billion, would ostensibly keep the Mississippi in check with new levees, dredging, and containment dams—all of this to control what is calculated to be the worst flood (the Design or Project Flood) of nearly 85,000 m^3/s at Old River.

Meanwhile, every shopping centre, every drainage improvement, and every square foot of new pavement in nearly half of the United States is accelerating runoff toward Louisiana. The precipitation that produced the 1973 flood was only about 20 per cent above normal, and while the high water did not even come close to being a Project Flood, it came very close to wiping out the control structure at Old River.

After spending $500 million on original construction and repairs to Old River, the Corps remains hopeful the structure will hold if, and when, the Design Flood comes. They admit, however, that the 'battle with Mother Nature' is far from over.

The desire to prevail over nature is still a frequent human response to growth pressures. Locally-occurring water shortages, for example, are often viewed merely as imbalances in the overall supply picture which can be overcome by damming rivers or importing 'surplus' water from regions where there is little human activity. The use of waterbodies as receptors for human and industrial wastes is predicated on the assumption that waterways can always dispose of them. Only when water pollution problems become serious enough to warrant concern is action taken to remediate them, and despite advances in the technology of pollution abatement, the removal of all contaminants is often considered unrealistic and too expensive.

Human impacts on the water resource go beyond the assaults on rivers, lakes and coastal waters. Farming, forestry, mining, fossil-fuel burning, smelting, urban runoff and landfill seepage all contribute to water pollution because of water's interrelationship with land and air through the hydrologic cycle. But whether our activities directly or indirectly affect water, the risk is the same: we may be irreversibly damaging a resource that is of utmost importance to us and to all life forms.

No-one, of course, wants this to happen, yet long-held beliefs and behaviours will not be easily changed. Perhaps a place to start is to see our relationship with nature as *ecocentric* rather than egocentric, as one of partnership and stewardship rather than domination and exploitation. The earliest expressions of this relationship can be found in the beliefs of aboriginal people, who attribute living souls to plants, animals and inanimate objects. In Western culture, ecocentrism found expression in the transcendental writings of Muir and Thoreau, naturalists who described nature as beautiful, morally healing and exercising spiritual power

over man. Their ideas spawned the wilderness preservation movement in Canada and the United States, and groups like the National Audubon Society and the Sierra Club. More recently, the relationship between humankind and nature has found expression in Buckminster Fuller's analogy of Spaceship Earth: the planet, depending only upon solar energy and its endemic resource base, is a place where life can flourish. Human activity must therefore be compatible with the planet's regenerative capabilities.

The rationale of ecocentrism becomes particularly meaningful when we consider that Canada is a country where the development of resources like water forms the backbone of the economy. If we degrade these resources, we also undermine our economic base, and our attempts at development become self-defeating. Alternatively, we can promote the kind of development that preserves the integrity and sustainability of resources. This concept, known as *sustainable development*, has been advocated by the World Commission on Economy and Environment and widely discussed in Europe and North America. At the core of the concept is the requirement that we not diminish our future quality of life and that we maintain the ecosystem so that our children can live equally as well as or better than we do. Sustainable development does not seek to limit economic growth *per se*, nor does it require protection of all resources. It simply means that the economy and the environment must be jointly managed for the long term.

Sustainability, whether it is associated with development or not, is a conservation strategy for protecting and preserving what remains of our resources and restoring the delicate balance between ourselves and nature. But the concept of sustainability goes beyond the continued existence of the biophysical life-support system. It delves into the cultural roots and consequences of human activity and challenges us to re-examine the nature of social behaviours and decision-making. If we see water as simply a commodity to enhance our lifestyle and standard of living, then we will also continue to support those policies and practices that place human needs before those of other organisms. And if we dismiss the impact of human activity on the environment as the inevitable price of doing business, then we are less likely to defend attempts to clean up the environment and to afford a greater degree of protection to aquatic ecosystems.

Ultimately, water is as interconnected with the biophysical environment as it is with our history, our development as a society, our present needs and wants, and our future. This fact alone will force us to more closely examine the consequences of our actions. If we are to sustain our water resources into the next century and beyond, we will need to harmonize our short-term goals with the aspirations, dreams and well-being of the generations that follow.

Study Two: The Water Resource

Of the 1,420 million cubic kilometres of water on the planet, about 95 per cent is found in the oceans and seas which cover nearly three-quarters of the earth's surface. This water is saline—that is, it contains dissolved salts, mainly sodium chloride, and is undrinkable. The remainder is found in the atmosphere, in glaciers, in the soil and underground reservoirs, and in streams, lakes and wetlands.

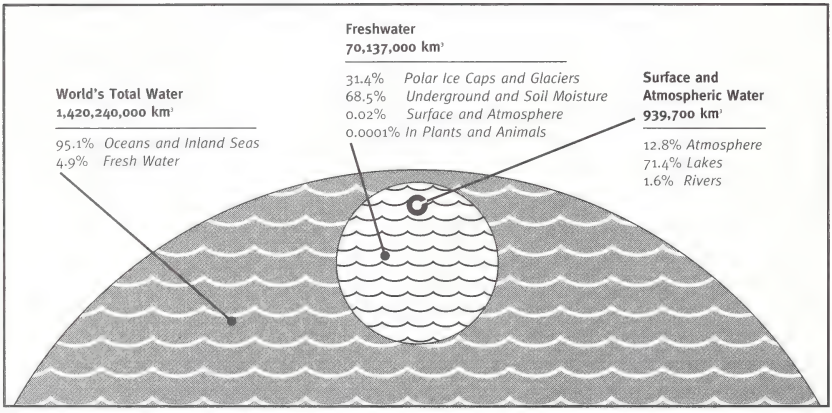


Figure 2: *Global Water Supply–Estimates vary, but of all the water on earth, only a tiny fraction–just a few hundreths of one per cent–is readily available as a supply of fresh water for plants and animals.*

A little more than one hundredth of one per cent of the total amount of water on earth is readily available as a supply of fresh water. It is this small fraction—in our lakes and rivers—that supports terrestrial life and the majority of human needs. The amount of groundwater world-wide exceeds the volume of lakes and river flows many times, but our ability to use it is limited by its location, depth and quality, and by our ability to tap it.

The ultimate source of fresh water is the *hydrologic cycle*. Through this cycle, water vapour in the atmosphere condenses and falls to earth as various forms of precipitation. Some of the water on the surface evaporates back into the atmosphere and some is taken up by plants and later lost by *transpiration* (a process by which plants release water vapour through their leaves). The remainder percolates down below the soil layer or returns to the oceans as river flow.

The hydrologic cycle is powered by solar energy. This energy directly or indirectly causes evapo-transpiration and the movement of air masses which transport water vapour. Water, in the strictest sense, is a renewable resource because it is

replenished every year. Were the cycle to cease, there would be no precipitation to maintain rivers, lakes and soil moisture, and all water would revert to the oceans.

On a global scale, the total amount of precipitation is equal to the total amount of evaporation, roughly 500,000 cubic kilometres of water annually. It is of utmost importance to terrestrial life that a disproportionate amount of precipitation falls on land. Whereas the continents lose 70,000 cubic kilometres of water to evaporation, they receive 110,000 from rain and snow. The net effect of the hydrologic cycle is to transfer some 40,000 cubic kilometres of fresh water from the oceans to the continents every year.

One might presume that this immense volume of water is sufficient to supply all human needs for the foreseeable future. Such is not the case, however. First of all, a good portion of precipitation is lost through floods or held within the soil and wetlands. As well, some rivers flow through regions that are climatically unsuitable for human settlement. But more important, there are wide variations in the distribution of precipitation world-wide, even within small regions of the planet: for example, Khartoum, in the Sudan, receives 158 millimetres annually; Aden, in South Yemen, 46 millimetres, and Baghdad, 140 millimitres. Climatic differences, more than anything else, account for the fact that some nations are water-rich, while others are water-poor.

Canada's Water Wealth

Canada, in comparison with many other nations, is well endowed with fresh water supplies. We average 600 millimetres of precipitation annually, although certain regions, such as the Pacific coast, receive considerably more precipitation and others, namely the western prairies and the high arctic, much less. Over a third of this country's precipitation falls as snow, accumulating during the winter months and melting to swell our rivers in the spring.

We also have been blessed with a storehouse of *fossil* water deposited in our lakes over 6,000 years ago by retreating glaciers. Lakes, in fact, cover eight per cent of our land surface, more than that of any country in the world. Wetlands increase this figure to 20 per cent. Canada shares with the United States seven of the world's largest lakes, and the Great Lakes collectively are the second-largest reservoir of fresh water in the world, after Lake Baikal in the former Soviet Union. Almost nine per cent of the world's total annual runoff flows in our rivers, more than all countries except the former Soviet Union and Brazil. Combined, our lakes and rivers contain enough water to flood the entire country to a depth of two metres. To put this water wealth in perspective, Canada's river flows afford each Canadian 130,000 cubic metres annually or almost 360,000 litres per day. In contrast, global river flows on a per capita basis average 8,300 cubic metres annually, and in countries like Egypt, only 90 cubic metres annually.

Surface Sources

Freshwater lakes around the world represent only a fraction of all free water, yet they constitute more than 98 per cent of continental surface waters available for use by people. The largest lakes in Canada are the Great Lakes (Superior, Huron, Erie and Ontario—Lake Michigan lies totally within the United States), Great Bear and Great Slave Lakes in northwestern Canada and Lake Winnipeg in Manitoba. Forty-five Canadian lakes have surface areas exceeding 1,000 square kilometres, while 563 lakes exceed 100 square kilometres in surface area. Some of our relatively-large lakes are actually reservoirs created by damming major rivers. Lake Diefenbaker in Saskatchewan and Manicougan Lake in Québec are two well-known examples.

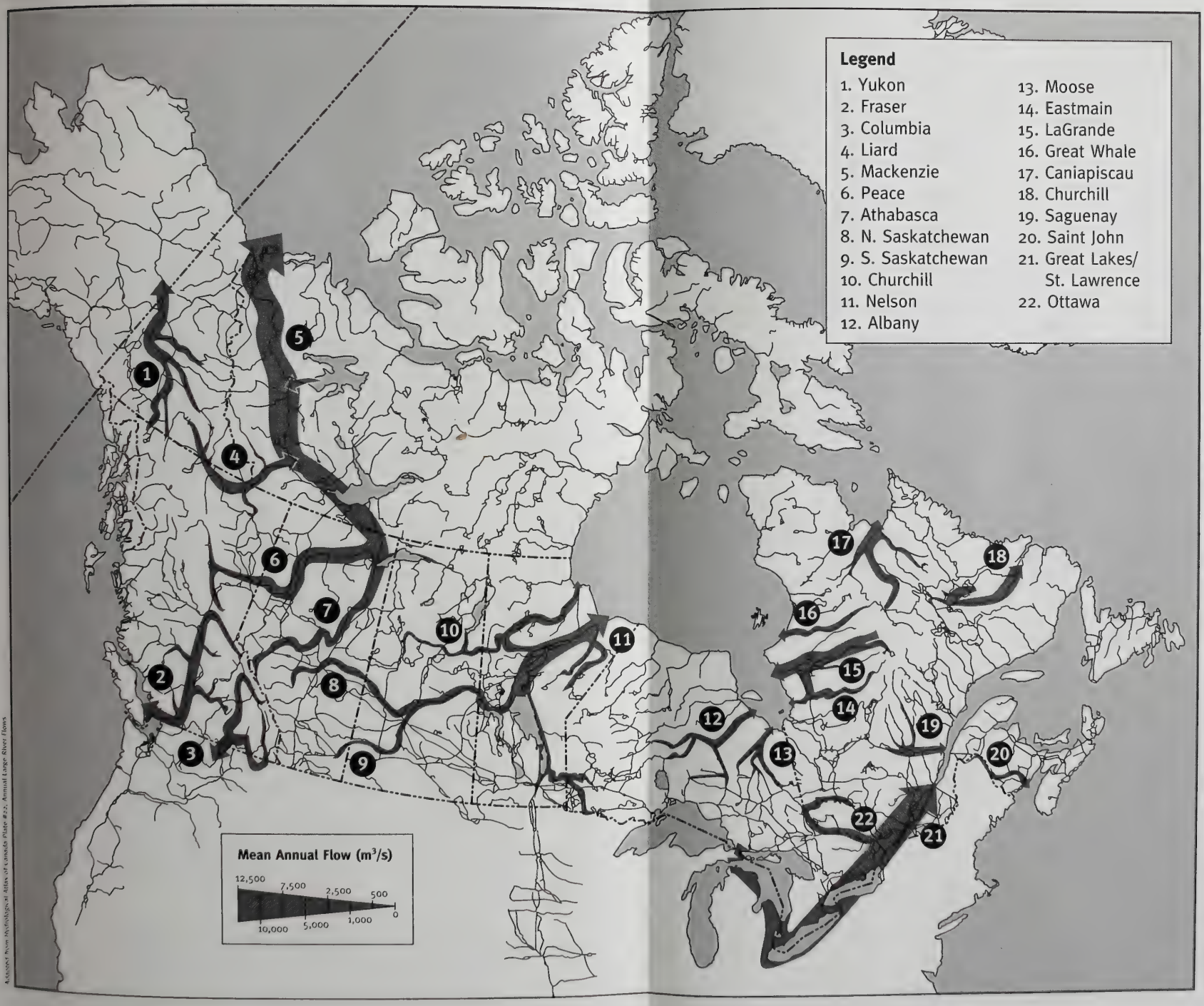
Even though Canadian lakes store a great deal of water, only a small portion of their supply is *renewable*. For example, 99 per cent of the water in the Great Lakes is a legacy from melting glaciers. Because most lakes have large volumes in relation to their surface area, their levels tend to remain fairly stable during periods of heavy runoff or drought. Thus, they are reliable sources of supply, at least in terms of quantity.

In contrast, the flow of water in rivers is almost totally renewed through the hydrologic cycle. This is because rivers are the recipients of precipitation running off the land's surface either as rain or melting snow. The entire catchment area, that is, the area that gathers runoff, is called a *river basin*, and includes a river and its tributaries. Most rivers in Canada originate in mountainous regions and flow toward oceans or bays containing salt water.

From a continental perspective, our rivers flow to five destinations: the Pacific Ocean, the Arctic Ocean, the Gulf of Mexico, Hudson's Bay and the Atlantic Ocean. The Pacific drainage basins, which include the Fraser, Columbia and Yukon Rivers, carry about 25 per cent of Canada's river flow. About 20 per cent of annual river flow drains into the Arctic Ocean. The westward-flowing Saskatchewan, Nelson and Churchill river systems discharge nearly 30 per cent of the national total into Hudson's Bay. Drainage to the Atlantic, which includes the Great Lakes-St. Lawrence basins, accounts for an additional 24 per cent. Less than one per cent of river water originating in Canada reaches the Gulf of Mexico via the Missouri-Mississippi drainage basin.

The St. Lawrence, in terms of sheer volume of flow, is Canada's largest river, while the Mackenzie drains the largest area and, flowing a distance of 4,200 kilometres, is the nation's longest. These two rivers and their tributaries drain about 14 per cent of Canada's land surface and account for about 19 per cent of this country's total river flows.

Water quantity surveys, initiated by the federal government in 1894, give us a comprehensive picture of how much water is in our rivers. Today, some 2,700



Adapted from Hydrological Atlas of Canada Plate #22: Annual Large River Flows

gauging stations measure flows on all major rivers in Canada and on many smaller streams. Much of the data on river flow comes from remote sensing stations and is fed through regional offices to computers in the Hull-Ottawa area. Although these data tell us the volume of flow (the *recorded flow*), they do not necessarily tell us *natural flows*—that is, how much water would be in the river if none were used. To determine natural flows, water that was consumed, diverted or stored must be added to the recorded flow.

River flows are usually expressed as volume of water over time, or *cubic metres/second (m^3/s)*, calculated to reflect a daily, monthly or annual average (or *mean flow*) either for a particular year or an historical period of time for which records have been kept. Flow measurements for the Assiniboine River at Brandon, Manitoba, reveal the following:

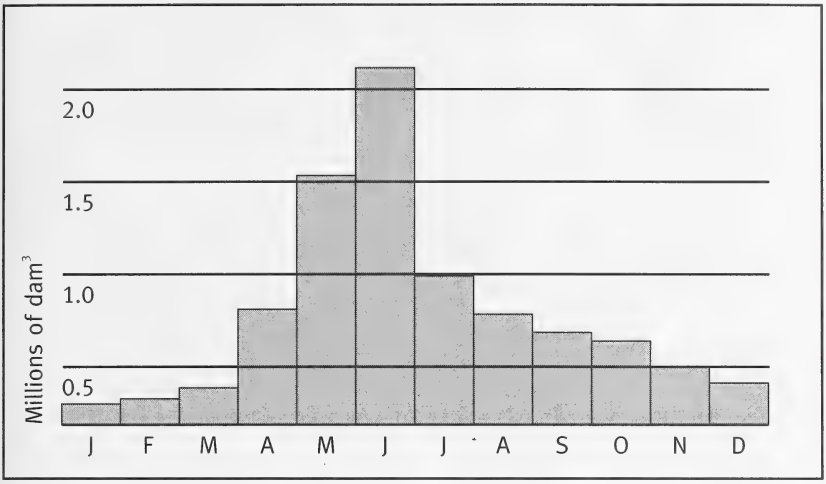
Table 1: Flow Measurements, Assiniboine River at Brandon

average flow during a day	1.58 m^3/s *(Feb. 7, 1937)*
average daily flows over a month	1.73 m^3/s *(Feb. 1937)*
average flow over one year	6.77 m^3/s *(1937)*
average daily flow for all years that records were kept	31.1 m^3/s

These figures illustrate the amount of streamflow variation which can occur in a river. Such variations can be understood if one recalls that rivers are fed by runoff which itself varies from day to day and from month to month. We can assume from the above data that flows in February were likely lower than during most other months, and that 1937 was a low-flow year compared with the historical average. We should emphasize here that seasonal streamflow is not as much a response to seasonal precipitation as it is to snowmelt. Whereas a good portion of rainfall evaporates back into the atmosphere, snow does not, and it is the melting of snow that causes the flush of water in our rivers during the spring.

One means of visualizing streamflow variation is through the use of a *flow-ratio hydrograph*, which plots monthly natural flow volumes over time (see Figure 1). In the example given, flow in the South Saskatchewan River at Bindloss, Saskatchewan, is lowest in January and highest in June. This hydrograph also tells us that the South Saskatchewan River passes about 60 per cent of its annual flow in a relatively short period of time (between mid-May and mid-July). The plots on the hydrograph represent average monthly flows in 1980. A hydrograph for any other year would show different monthly values, although the overall pattern (high spring flows, low winter flows) would be similar.

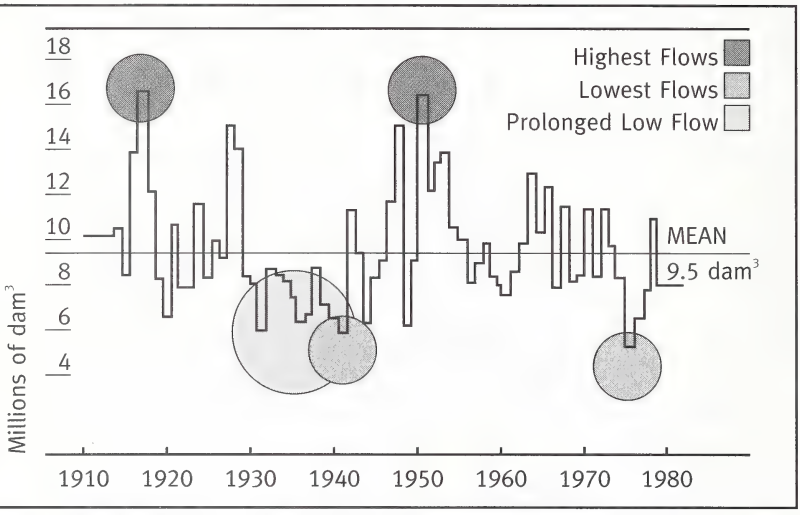
In Canada, river flows vary depending on temperature and precipitation. Prairie rivers characteristically have high flows in the spring and reduced flows the rest of the year. In the north, the lowest flows are usually during the winter when rivers are covered by ice or are frozen to the bottom. In contrast, the Nanaimo River on Vancouver Island has its highest runoff period during the rainy season in mid-winter.



Alberta Environmental Protection.

Figure 4: *Composite Hydrograph, South Saskatchewan River Basin, 1980–Rivers fed by melting snow characteristically have high flows in the spring and reduced flows during the winter. About 60 per cent of the South Saskatchewan River's annual flow is passed between mid-May and mid-July.*

In addition to daily, monthly and seasonal variations in streamflow, there can be significant variation in flow from year to year or over a period of years. *Annual flow rates* are calculated in larger units, *cubic decametres* (written as *dam*^{3}, a cubic decametre is equal to 1,000 cubic metres). A composite hydrograph (1912-1982) for the South Saskatchewan River at Bindloss (See Figure 5) shows annual flows as high as 16.6 million dam^3 in 1916 and 1951, and as low as 4.5 million dam^3 in 1941. From 1929 to 1941, during the 'dirty thirties' of the Great Depression, annual flows were consistently below the historical average of 9.5 million dam^3.



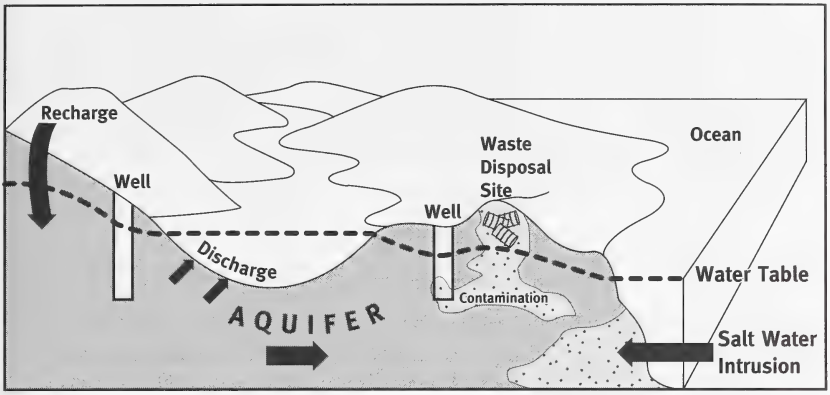
Source: Summary Report, South Saskatchewan River Basin Planning Program, Alberta Environmental Protection.

Figure 5: *Composite Natural Flow Hydrograph, South Saskatchewan River at Bindloss, Saskatchewan, 1912-1982–Annual flow variations can be extreme. During the 'Dirty Thirties', flows in the South Saskatchewan River were considerably below average.*

Groundwater Sources

About ten per cent of precipitation moves down through the soil until it reaches a zone of saturation, where water fills the spaces between grain particles and crevices or fractures in rock. The upper surface of the zone of saturation is called the *water table*. Water table depths vary from less than a metre to tens of metres below the surface. Like surface water, groundwater flows, generally moving from higher to lower elevations (e.g. stream valleys or lake beds). The volume and rate of groundwater flow are determined mainly by the composition of the underlying formation and by fractures found in the strata. The more porous formations—those consisting of sand and gravel—transmit water more freely.

Aquifers are water-bearing formations that will yield water in sufficient quantities to provide a viable water supply. Aquifers may be loosely packed or *unconsolidated* (consisting of sand or gravel), or *consolidated* (made up of sandstone or limestone). Even dense consolidated rock such as quartzite or granite may yield water if it is sufficently fractured or cracked. While all aquifers are *recharged* naturally by precipitation, the rate of recharge depends on the amount of precipitation, the depth of the aquifer and the composition of the underlying formation. Aquifers can be depleted by overpumping (sometimes called *water mining*). During a prolonged drought, the water table may drop below the depth of a well, and the well may go 'dry'.



Adapted from *A Primer on Freshwater*, Environment Canada, 1991

Figure 6: *Groundwater–About 10 per cent of precipitation moves down through the soil, filling spaces between sand, gravel or rock to create aquifers that can yield water for human use–or be contaminated by improper waste disposal.*

Wells drilled into aquifers will yield water in varying amounts, depending on the size and composition of the underlying water-bearing formations and the rate of recharge. Wells in river valleys or overlying unconsolidated aquifers may yield over 2,000 litres of water per minute, while those in regions receiving very little precipitation or on top of consolidated aquifers may draw ten litres per minute or less. For example, aquifers in New Brunswick will yield from 90 to 2,270 litres/minute, while those in the Charlottetown area supply from 158 to 210 litres/minute. These aquifers are overlain by sandstone and are capable of supplying entire communities. In contrast, the aquifers around Halifax-Dartmouth are overlain by fractured granite, slate and quartzite, and wells here yield only between 4.5 and 23 litres/minute, enough for an individual family.

Groundwater exists everywhere beneath the land surface and in amounts that greatly exceed water on the surface and in the atmosphere. Our knowledge of groundwater deposits comes mainly from drilling records, although the federal and provincial governments are currently compiling groundwater inventories. The total volume of fresh water in Canadian aquifers is unknown, but it is certainly larger than the total volume of the Great Lakes. What is known is that the use of groundwater has grown. In the 1960s, only about ten per cent of the population relied on groundwater. This figure increased to about 26 per cent in 1981, when the most recent studies were done. Even though water from rivers and lakes constitutes the greatest source of supply in Canada, certain regions, particularly the Maritimes, depend almost exclusively on groundwater.

Groundwater and surface water form a single system. Streams and lakes overlying permeable beds can recharge the water table. But more often, surface water is augmented by groundwater. During periods of little rainfall, water flowing in a

stream may come almost entirely from subterranean sources. Additional evidence of the interconnectedness of ground and surface water comes from coastal regions. Normally, pressure from the aquifers will confine sea water to a *zone of diffusion* a certain distance from the shoreline. During dry periods, extensive well pumping relaxes the seaward pressure and allows salt water to move further inland. This phenomenon, called *salt water intrusion*, is responsible for the saltwater contamination of wells, and is not uncommon in Atlantic Canada.

Water Quality

We seldom see water in its pure form. Even rainwater has traces of other substances, such as dissolved gases emitted by cars, factories and fossil fuel-burning plants. The *quality* of water is determined by the concentration of other substances in pure water. These concentrations are expressed as *milligrams of substance per litre* of water (mg/L) or as *parts per million* (ppm)—one part substance to one million parts water.

The natural quality of water is affected by sediments, evaporation, temperature, and the kinds of soils and rocks that water moves through and over. Water *hardness*, for example, is caused by the presence of calcium bicarbonate from eroded limestone. Taste, odour, colour and *turbidity* (cloudiness) of surface waterbodies may result from decaying organic matter or sediments. Water evaporating from a pond or shallow lake concentrates dissolved salts. Waterbodies may contain micro-organisms that are naturally present or come from surface runoff. Groundwater, because it is filtered by the soil, is generally free from micro-organisms and sediments, but may contain iron, calcium, magnesium and sodium in dissolved form.

Lakes undergo a natural aging process known as *eutrophication*. Like all living things, lakes have a life span, usually measured in thousands of years. An *oligotrophic* or 'young' lake is clear, cold and lacking in nutrients to sustain aquatic life. Aging occurs as nutrients, plants and sediments reach the lake in runoff. As this happens, the variety and numbers of life forms increase, and their deaths enrich the lake and add to the accumulating debris on the bottom. The lake has become *mesotrophic* or middle-aged. Over time, the lake continues to become narrower, shallower and warmer and reaches the *eutrophic* stage—highly fertile, with abundant plant growth. The process continues as the lake gradually becomes a marsh, finally ending up as dry land. The speed of this process depends on the volume and depth of the lake and the fertility of the surrounding watershed.

Water quality is also affected by human and industrial wastes and a large number of chemicals used in agriculture, forestry and manufacturing. Water quality concerns us because man-made contaminants can render the supply unsuitable for human use and endanger the survival of aquatic life. It is important, therefore, to know what these contaminants are and how they enter the water supply.

All surface waters contain organic matter from natural and man-made sources. Bacteria in water digest or decompose organic matter and, in the process, consume oxygen. The amount of oxygen required for bacterial decomposition is called *biochemical oxygen demand*, or *BOD*. Human sewage and industrial wastes from pulp mills, tanneries and food processing plants add large quantities of BOD to lakes and rivers, and may cause oxygen depletion, leading to death of fish and other aquatic organisms.

Solid material in water can be present in either *dissolved* or *suspended* form. Those substances that dissolve (salts, for example) are separated by water into distinct molecules, and are so tiny that they remain in solution. But many solids—grains of soil, rock or clay—are suspended in water (they do not break down into molecules) and will eventually settle out on the bottom of a river or lake. Particles which are very small but are still larger than molecules are called *colloids* and will remain in suspension indefinitely. Solids can also be classified as *organic* or *inorganic*. Organic solids can exist in dissolved or suspended form, but unlike inorganics they consume oxygen during their decomposition in water. (Human sewage is an example.) In water quality analysis, the term *total dissolved solids* (*TDS*) serves as an index of salts and organics. *Total suspended solids* (*TSS*) and *total solids* (*TS*) are other commonly-used measures of solids in water.

Nitrogen and *phosphorus* are essential plant nutrients which are invariably present in dissolved form. In high concentrations, they can stimulate weed and algae growth, causing odour and aesthetic problems and lowering *dissolved oxygen* levels when these plants die and decay. These two nutrients are present in human sewage and agricultural runoff containing fertilizers. For purposes of water quality analysis, nitrogen and phosphorus may be grouped with other dissolved solids or may be listed separately.

Bacteria and protozoa are common to surface waters unaffected by human activities but rarely cause water quality problems. On the other hand, bacterial and viral contamination from human wastes, even after treatment, can render water supplies unsuitable for drinking and contact recreation (swimming). *Total coliforms* and *fecal coliforms* are two frequently-measured indicators of bacterial contamination of surface waters.

Toxic substances, or *toxics*, are those which pose a threat to ecosystems or human health. Although some toxics, like mercury, are naturally present in surface waters, their concentrations are usually very low. The toxic substances that concern us most are synthetic chemicals entering surface or groundwater supplies from direct discharge, seepage or runoff. Some toxic chemicals are organic compounds that contain chlorine, such as DDT, a commonly-used pesticide that eventually was banned from use. Polychlorinated biphenyls (PCBs) and polyaromatic hydrocarbons (PAHs) are members of this group. *Heavy metals* such as mercury, lead and arsenic are also known to be toxic.

Atmospheric pollutants are known to dissolve in water, either in the atmosphere or when they combine with moisture on the ground. It is now well established that oxides of nitrogen and sulphur are responsible for the acidification of lakes and streams, particularly in eastern Canada, as well as the degradation of forests, crops and buildings. *Thermal pollution* by warm-water discharges from thermal and nuclear power and industrial plants can raise water temperatures in lakes and rivers, affecting the metabolism of fish and other aquatic organisms. Practices associated with the mining of uranium and storage of nuclear wastes have raised concerns that water supplies might become contaminated by radioactive materials which are known to cause mutations and cancer.

The source of contamination can be categorized as being *point* or *non-point*. *Point* sources directly discharge contaminants into the environment (a municipal or industrial wastewater treatment plant is an example). Of the two types, point sources are the easier to identify, monitor and control . *Non-point* sources sometimes called *diffuse sources*) are much harder to identify and control because contaminants enter surface and groundwater by surface runoff or seepage, and the exact source may be difficult to locate. The distinction beween point and non-point sources is important in proving cause-effect relationships between the source of contamination and the direct impact of that source on water quality.

The State of the Water Supply in Canada

Some observers have stated that the crisis of the future will not be one of energy but of water. Just how serious is the situation in Canada? At first glance it seems unlikely, given the nation's prodigious river flows, that we would ever run out of water. Yet 60 per cent of this flow drains northward, while nine out of every ten Canadians live within 300 kilometres of our southern border. And, as we have seen, river flows are subject to seasonal and annual variations that can, in some cases, be extreme.

The mean annual flow of Canadian rivers is about 105,000 m^3/s, or an annual transfer of 3.3 trillion m^3 of water to the oceans. This large volume of water is fifty times greater than current withdrawals. But such supply figures are misleading because they mask periods of very high or very low runoff. *Reliable flows*—flows that can be expected nine out of every ten years, or, in some cases, nineteen of twenty—give us a more realistic appraisal of the water supply, for it is this supply on which cities, industries and irrigation farmers depend. The volume of streamflow that we could expect 95 per cent of the time is about 76 million m^3/s, or about three-quarters of the average annual flow rate.

From a national perspective, we are still a water-rich country. Not all regions of Canada, however, are blessed with such abundance. In the Assiniboine-Red Basin of southern Saskatchewan and Manitoba, withdrawals now exceed reliable annual flows by a considerable margin, and in the South Saskatchewan River Basin,

reliable flows could be surpassed in thirty years, given current projections for irrigation development. Prairie rivers are also characterized by poor water quality, especially during the dry summer months when the combined effects of reduced flows and agricultural runoff produce tepid water and unsightly algae blooms. In the British Columbia interior, Okanagan Lake and the Okanagan River experience similar problems.

In contrast, the Great Lakes region has ample rainfall and the immense volume of the lakes themselves. But the renewable supply of water is only one per cent of the lakes' total volume. The region supports a population of over 37 million. Although water withdrawals from the Great Lakes are more than offset by precipitation, runoff and tributary flow, increases in demands could lower lake levels by the year 2035.

Water quality is influenced by water quantity. Even fairly high concentrations of contaminants from point and non-point sources can be diluted until they are not very noticeable. There are limits, however, to the amount of contaminants even large bodies of water can absorb. Tonnes of nutrients from partially treated urban sewage and farm runoff almost spelled the demise of Lake Erie in the late 1960s, requiring both the United States and Canada to implement wastewater treatment and reduce phosphorus loadings. Today, urgent measures are needed to deal with toxic contamination of drinking water.

Despite the immensity of our oceans, they too are beginning to show the effects of pollution after decades of abuse. Coastal cities, including Vancouver, Halifax and Saint John, New Brunswick, routinely dump raw and partially-treated sewage into estuaries and harbours. Caraguet Bay in northwestern New Brunswick produces 70 per cent of the province's catch of oysters, but 2,400 hectares of its shoreline is now closed to the harvest of shellfish because of fecal contamination. Elevated levels of heavy metals in the marine life of the Fraser estuary are thought to orginate in the industrial waste discharges of Vancouver industries. The beluga whale, a long-time resident of the St. Lawrence estuary, is now being threatened by organochlorines from the Great Lakes and Québec industries lining the shores of the St. Lawrence and Saguenay Rivers.

Even the most fouled waters will eventually cleanse themselves if we stop polluting them. Water below the ground, once degraded, will never recover. Groundwater contamination is not as severe here as it is in the United States, but we still have cause for concern. In Prince Edward Island and New Brunswick, wells have been found to contain worrying levels of aldicarb, an agricultural pesticide. Chemical wastes originating from an old gravel pit seeped into the aquifer serving the population of Mercier, Québec. A PCB spill near Regina threatened to contaminate the underground water supply of that city, and public anxiety was only relieved after it was determined that the chemical had not entered the aquifer. Chlorophenols from a sawmill near Penticton, British Columbia, almost reached the

Okanagan River before they were removed by pumping them out of the ground. And these are just a few examples.

How is it that a nation with nearly 20 per cent of the world's fresh water but only one per cent of its population is now experiencing water shortages in certain regions and pollution of its rivers, lakes and aquifers? Part of the answer lies in what the late Dr. Derrick Sewell and other authors have called the *myth of superabundance*. This belief is predicated on the assumption that Canada has enormous, even unlimited water resources capable of supporting unbridled growth, and that Canada's water woes are simply the result of uneven population densities and regional disparities in the supply. If one believes this myth, then it is easy to see how overconsumption and pollution of water resources might be rationalized. While water is a renewable resource, it is also finite, and if we run out, there is simply no way of making more of it.

Discussion Questions

1. The Telecourse theme, water's *interconnectedness*, refers to its association with both the biophysical environment and human society. What are your personal interconnections with water and how are they shaped by your own values, beliefs and attitudes?

2. Explain how water can be both a finite and a renewable resource. What implication does the distinction between the two terms have for the long-term use and management of water resources in Canada?

3. Would you say that our approaches to water management in Canada reflect an *egocentric* or *ecocentric* view of nature? Defend your answer with concrete examples from the telecourse.

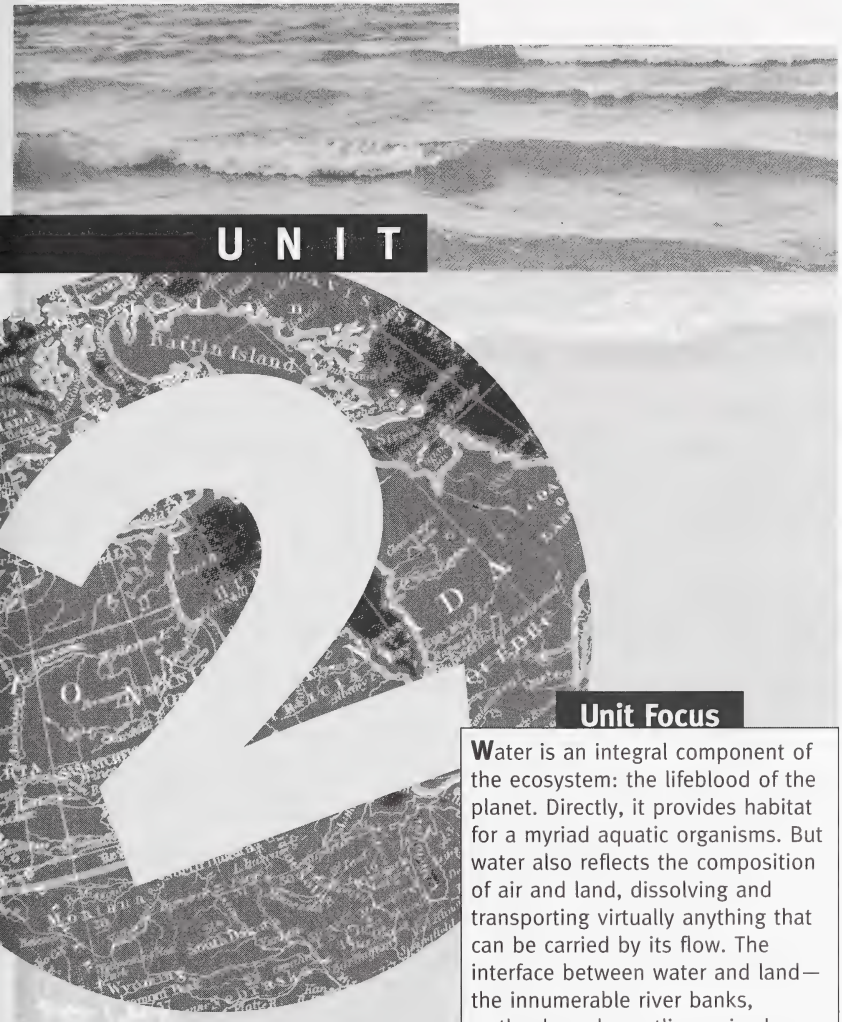
4. In your opinion, is our present use of resources sustainable or unsustainable in the long term? Why or why not?

Recommended Readings

Currents of Change: Final Report, Inquiry on Federal Water Policy
Françoise Bertrand, James McLaren and Peter Pearce, Environment Canada, 1985. *A comprehensive and far-reaching report on water use and management in Canada and the challenges facing this country in the future.*

To the Last Drop, Canada and the World's Water Crisis
Michael Keating, Macmillan of Canada, 1986. *A thorough investigation of water-related issues and problems in Canada.*

Our Common Seas: Coasts in Crisis
Don Hinrichsen, Earthscan Publications Ltd (London), 1990. *Examines problems of the world's oceans and strategies for international co-operation in reversing pollution and destruction of inshore ecosystems.*



UNIT 2

Unit Focus

Water is an integral component of the ecosystem: the lifeblood of the planet. Directly, it provides habitat for a myriad aquatic organisms. But water also reflects the composition of air and land, dissolving and transporting virtually anything that can be carried by its flow. The interface between water and land—the innumerable river banks, wetlands and coastlines—is also a place attractive to humans, and our activities influence both the quantity and quality of water available to other forms of life. Our voracious appetite for water—for irrigation, industrial development, power generation and waste disposal—must be tempered with efforts to protect the environment which water supports.

Unit Objectives

At the conclusion of the unit, you should be able to:

1. trace the movement of water through the *hydrologic cycle*
2. explain how water's quantity and quality affect aquatic habitat
3. describe the feeding sequence in *food chains* and *food webs*
4. summarize the process of aging in lakes (*eutrophication*)
5. define *biomagnification*
6. distinguish between *instream* and *withdrawal uses* of water
7. illustrate the use of water by various sectors (e.g. municipal, industrial, agricultural, electrical energy generation).

Key Concepts

At the conclusion of the unit, you should understand that:

1. the supply of fresh water is renewed by the hydrologic cycle
2. proximity to water has been a major factor in the location of communities and industries in Canada
3. water has a great capacity for transporting solutes and sediments throughout the biosphere
4. water provides habitat for aquatic plant and animal species and each has adapted over time to changing conditions of water quantity and quality
5. urban growth along with industrial and agricultural development have improved the quality of life for humans but have also degraded the environment
6. the impacts of human activity on the environment can be ameliorated through a better understanding of air/land/water interrelationships
7. water consumption is influenced by technological changes in the way water is used and managed.

Hour Two Overview

Seen from space, Earth is a small and fragile ball dominated not by human activity and edifice but by ever-changing patterns of cloud over a tapestry of oceans, greenery and soils. The image is both fascinating and worrisome: suspended in a void of lifelessness, the planet's life-support systems are threatened by human-induced change. Yet it is our home, and we must sustain it not only for ourselves but for all life, and for future generations.

In today's parlance, Earth and *ecosystem* have, somewhat erroneously, become synonymous. The latter term, derived from the Greek *ecos*, or house, suggests not only a place but a set of interdependencies between living and non-living components. These interdependencies can be as simple as a single plant cell's need for sunlight or as complex as a human's needs for food, shelter and spiritual sustenance. Like the layers of an onion, each such ecosystem is contained within larger and larger ecosystems and their totality, that fascinating and worrisome image, is properly referred to as the *ecosphere* or biosphere.

Common to all ecosystems is the need for water and, more than any other component, water is the link within and between ecosystems. These *interconnections*—between plant and animal life, with land and air, and their interplay with human needs and wants—are the focus of *The Living Flow's* second hour.

The essay **FLOW** explores the importance of flow patterns in the maintenance of ecosystems, and a number of impacts caused by human changes to these flows. **TIDES** spins a real life 'fish tale' that reveals how the ebb and flow of human activity has accelerated the 'natural' pollution of lakes and rivers, and shows how human ingenuity and perseverance have been able to reverse the damage. **SYMPHONY** follows the course of rivers across the land, demonstrating the destruction and rehabilitation of fish-spawning habitat, and showing the need to harmonize human land uses with the music rivers play as they meander across our lives.

FLOW—Essay Description

"But it wasn't an opening, of course. It was a closing... a closing that would reverberate for thousands of kilometres and dozens of years. For the Bennett Dam had gone Against the Flow."

When the W.A.C. Bennett Dam on the Peace River opened in 1967, it was a cause for celebration. The massive earth-fill dam would not only provide flood control for downstream communities, it would put 'wasted' water to good use, sending it roaring through turbines to generate power for British Columbia's continued growth.

Twelve hundred kilometres downstream, aboriginal trappers suddenly found their livelihood draining away. For centuries, rivers draining the Peace-Athabasca delta (a 5,000-square-kilometre World Heritage wetland located at the southern end of Wood Buffalo National Park) had been slowed by the Peace River's vastly higher flows. But during the almost three years it took to fill Williston Lake behind the dam, the 'Mighty Peace' was reduced to, comparatively speaking, a 90-pound weakling. No longer held in check, the delta drained rapidly, leaving thousands of hectares of mudflats as the most visible result.

British Columbia refused to accept responsibility, and damage control fell to the federal government and the provinces of Alberta and Saskatchewan. After intense study, their major response was to build weirs across two of the rivers draining the delta in order to maintain minimum water levels. Crisis averted? No, just delayed.

The delta's productivity depends on periodic high floods that replenish thousands of small ponds and lakes known as *perch basins* or *perched basins*. With the Peace now a 'flow controlled' river, peak flood levels have been reduced by half a metre, enough to leave many of the perch basins high and drying. And as they dry, *succession* proceeds: wet sedge meadows are replaced by grasses, grasses by small shrubs, shrubs by trees. Studies of satellite photos show a loss of wetland area in the order of 20 per cent, and an almost 40 per cent loss of sedge meadows between 1976 and 1989. Migratory waterfowl and the Park's bison herd are caught in the squeeze. As their habitat declines, they will too.

Lengthy time scales and compounding effects are the norm when human activities go against the flow. The acidification of Québec maple bushes likely started several decades ago but *dieback*—the slow death of trees from the top down—only became apparent in the late 1970s. Although there is still some dispute over acidification's exact role, the death of the trees triggers other changes: ferns come to dominate the forest floor, crowding out maple saplings; soil organisms and insect populations change, affecting bird populations; and an unnatural silence descends. Studies of lake acidification show food chains collapsing both from the

disappearance of aquatic plants and algae and from interference with the reproduction of different species. Ironically, highly acidified lakes appear crystal clear—but predator fish like lake trout slowly starve in these 'pristine' waters.

TIDES—Essay Description

"For instance, did you know there are tides here, even though it's a thousand kilometres to the nearest ocean?

"You see, they're not lunar tides. They're human."

Sprawling across the Alberta foothills, today's Calgary bears little resemblance to the 'city' created by the Canadian Pacific Railway at the confluence of the Bow and the Elbow Rivers. But in more than a century, one thing hasn't changed for the city's residents, now 700,000 strong: they depend on their rivers for drinking water, hydroelectricity and sewage disposal. And the Bow provides another benefit: a trout fishery worth $11 million a year to the city—but that's a real 'fish tale'.

We may be individuals, but in groups we're amazingly predictable. Like ocean tides, our combined demands for water, sewage disposal and electricity rise and fall across the day and over the year. For TransAlta Utilities, the highest electricity demand occurs in the winter, so their network of Bow River hydro plants stores water for winter release. These releases are both erratic—they rise and fall as the utility tracks power demand, requiring a dam on the city's outskirts to smooth out the flows—and beneficial—the extra winter flows protect the river against Calgary's tides of *biochemical oxygen demand:* in a word, sewage.

Without this protection, *dissolved oxygen* levels might fall to the point of killing the trophy-size trout anglers hook by the hundreds. Their size is testament to the fertilizing power of sewage in an aquatic ecosystem, but you can have too much of a good thing and the Bow almost succumbed to *overfertilization*.

Ontario's Lake Erie, too, came close to this fate. In the late 1960s, massive discharges of sewage and industrial wastes were turning the lake *eutrophic* and Erie's 'rescue' was demanded. But there was scientific and public controversy over the most effective methods, in particular over mooted controls on the nutrient phosphorus (used at the time in many laundry detergents to provide that 'whiter-than-white' state of perfection).

With a shot of phosphorus heard around the world, researchers at the Experimental Lakes Area, near Kenora, Ontario, cut the controversy short. Separated by a vinyl sea-curtain, the two halves of Lake 226 were fed different diets. The side receiving phosphorus turned a rich blue-green from algae, one of

the symptoms of eutrophication. No further proof was needed and phosphorus controls were legislated for Lake Erie, and later for the Bow River.

Today, Erie's decline has been reversed and management of the entire Bow system seeks to maintain a balance between hydro releases, irrigation withdrawals, and sewage discharges that protect the fishery. Calgary's citizens are linked to their rivers by their own tides. It's not always an easy harmony.

SYMPHONY—Essay Description

> *"Of course, humans may hit the B-Flat across a whole reach of river. You can take this wonderful, undulating, plunging, diverse piece of water and turn it into a single solemn column that goes shooting down across the landscape."*

In the late 1940s and early 1950s, Dauphin Lake in Manitoba supported a productive winter fishery. Several species including goldeye and walleye provided a rich annual harvest (over 200,000 pounds per year of walleye alone). But starting in the early 1950s, the catch started to plummet. Just ten years later, the walleye catch was barely 10,000 pounds. Some thought the Lake was overfished; others looked further.

Agricultural settlement invariably increases both runoff and the resulting erosion. As clearing progressed, the basin's rivers became more and more prone to flooding—a 'simple engineering problem' that a major program of flood control attempted to solve in the late 1940s and early 1950s. Rivers were deepened, straightened and channelized to move water off the land and to the Lake in a minimum of time and, it turned out, with a maximum of erosion. Every year, over 500,000 tonnes of soil swept down these 'improved' waterways and into the Lake, blocking the light needed for plant growth and blanketing the bottom with as much as a metre of sediment.

This damage was compounded by the loss of *pool and riffle* sequences in the channelized rivers. Apart from moderating erosion by slowing a river's flow, these pools and small rapids provide spawning habitat for fish like walleye. Flood control removed them and the consequence, a decline in walleye reproduction, showed up as declining catches.

Restoring the fishery requires rehabilitation of the affected waterways. Following research on natural riffle zones, loads of rock have been used to build artificial riffles. Follow-up research shows these structures not only moderate erosion, but walleye and other stream-spawning fish are using them for reproduction. For

Dauphin Lake's fishery, the signs are hopeful, but stream rehabilitation is just a first step towards a sustainable future for the basin's residents.

The next step has to take place on hundreds of farms, where land-use patterns contribute to erosion. *Farming for Tomorrow*, a joint program of the federal and provincial governments, is one of several efforts to help farmers make their operations sustainable. But that's just a second step. The basin has been designated Manitoba's first demonstration project for sustainable development and an advisory group representing 48 different organizations is charting the future. Differences of opinion are strong... but all realize the only way forward is to work together.

Study Three: Water and Ecosystems

When humans were first able to see the earth from space during the mid-1960s, they were impressed by both the beauty and vulnerability of the planet. To them, the earth appeared to be a life-support system in a void of lifelessness, with no other input from the universe than solar radiation. The term *ecosystem* is most often applied to specific components of the earth in which distinct groups of organisms interact with their environment. However, the planet as a whole is also an ecosystem as the overall balance of life is dependent upon complex interactions between these components.

Water plays a prominent role in these interactions. It is perhaps nature's best solvent: more chemical substances will dissolve in water than in any other liquid. Water molecules are slightly *polar* (they attract and separate other substances into small particles) and this property is primarily responsible for the mixing that occurs in a water solution. Water is also a transporter of *solutes*, a fact that accounts for the presence of dissolved nutrients, salts, minerals and gases in waterbodies and groundwater. The concentration of solutes in water is, in most instances, kept constant by continual uptake and recyling by plants and animals.

Water in motion is the earth's most powerful erosive force, creating mountain valleys, deltas and floodplains. We often see this erosive force in the sediment loads of rivers after a heavy rainstorm. These sediments are transported downstream where they eventually will be deposited in the river channel as the current slows down. For the most part, erosion is kept in check by a mantle of vegetation in which root systems hold the soil together and absorb its moisture. Forested areas, for example, help to control erosion by absorbing a great deal of precipitation before slowly releasing it into rivers or lakes.

Such descriptions of water's *carrying capacity* underscore a fundamental interrelationship between water and land. Virtually anything that can be dissolved

in water or carried in particulate form will be transported from one place to another—from the surface of the land into rivers, lakes and oceans or into the underlying strata. This transport of solutes and sediments is vital to the maintenance of aquatic ecosystems. For example, phosphorus and nitrogen, essential for plant growth, can only be used by plants in dissolved form. These nutrients are carried by water downward through the soil, where they can be absorbed by plant roots. Phosphorus and nitrogen are also carried by runoff into marshes and swamps, where they are incorporated into aquatic plants. As these plants die and decay, the nutrients are released into the water where they can be used again.

Water, then, can be considered the lifeblood of the planet, analogous to the blood in our own bodies which carries oxygen and nutrients and removes wastes. Natural processes cleanse water and keep it healthy. Human activity, on the other hand, can degrade water. We see this most clearly in the pollution of our rivers, lakes and coastal waters by human and industrial wastes. Less obvious, perhaps, are human impacts on the land. When we remove vegetation from fields and mountain slopes, we also remove the natural barriers against erosion. When we use chemicals on forests and crops, we add to the load of solutes water will transport in runoff. In these instances, we alter the processes affecting the water's suitability for sustaining life.

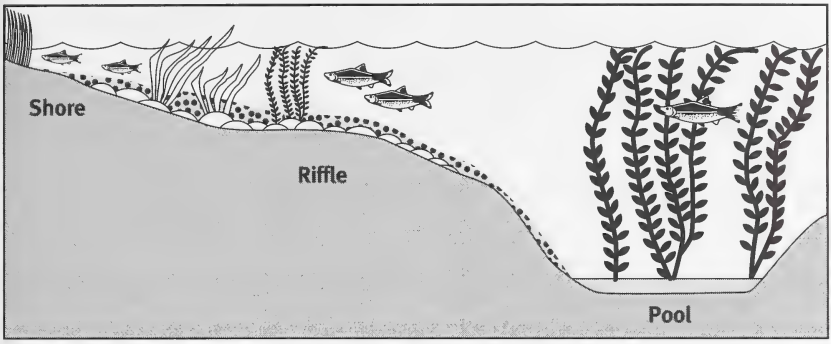
Habitat

The availability of water affects the distribution and variety of plants and animals. For example, where water is scarce, there are fewer numbers and kinds of organisms, and those that do exist have evolved mechanisms for protecting against water loss. The abundance of water, on the other hand, fosters a rich diversity of species. Water's role in aquatic ecosystems is even more pronounced. Here water provides habitat (both for those organisms that live in water and for those that depend on water for shelter), breeding and a source of food.

Rivers, lakes and *wetlands* (such as marshes, bogs, swamps, fens and deltas) contain fresh water, whereas oceans are saline. *Estuaries*, where fresh and salt water intermingle, are formed when rivers enter oceans. Aquatic ecosystems do not exist independent of each other or the adjacent landscape. They are influenced by the types and quantities of nutrients and sediments gathered in surface runoff.

Habitat is influenced by water quantity and quality. Fish, for example, are very sensitive to water temperatures and streamflow. Rainbow trout and mountain whitefish inhabit cold-water streams, whereas northern pike and walleye prefer water with warmer temperatures. If water temperatures were somehow to change, the cold-water species would likely be replaced by the warm-water species. Some species, such as salmon, migrate from the oceans to the headwaters of rivers to

find suitable spawning grounds. These spawning grounds are characterized by shallow, cold and rapidly-flowing water which is fresh rather than salty.



Program, Alberta Environmental Protection

Figure 7: *Fish Habitat–A natural consequence at a river's meandering, pools and riffles each provide important fish habitat.*

Freshwater fish must adapt to a range of conditions which change with the seasons and from year to year. Low river flows reduce habitat because there is less area covered by water. With less habitat, competition for food and spawning habitat increases, subjecting fish to more stress and making them more susceptible to predators and disease. Low flows may hinder the movement of adult fish to spawning areas or trap the fry (young fish) before they can reach deep water. High flows, on the other hand, can increase the amount of sediments in a river, suffocating eggs and covering food supplies. Occasionally, high flows are needed to flush out the sediments that cover spawning beds.

Fish live in habitats where they are surrounded by water. Wetlands, on the other hand, are inhabited by animals that spend much of their time on land but are still dependent on water for food and shelter. Waterfowl feed on aquatic insects, insect larvae and the grains of sedges and other aquatic grasses. Nests are constructed near water to afford the young easy access. The surrounding vegetation provides protection and resting areas.

Many fur-bearing mammals also live near water. Beavers must have fast-moving water to stimulate dam-building, as well as vegetation for lodge construction and food. Otters feed on insect larvae, amphibians, fish and other aquatic organisms. Mink and raccoon prefer marshes and swamps because of the fish they support, and muskrats eat aquatic plants. Other mammals, such as moose and deer, require drinking water, and browse on the aquatic plants of marshes and lakeshores. Water is vital to maintain aquatic food webs and living conditions of wetland inhabitants.

Wetlands are also a crucial part of the water cycle. *Marshes* slow down the flowing water from streams and rivers, allowing sediments to settle out. As well, marshes

absorb nutrients and decaying organic material brought in by streamflow. Water flowing out the other end of the marsh is much cleaner and suitable for fish and wildlife. For this function, wetlands have been described as 'nature's kidneys'. Wetlands also act as natural flood barriers because their vegetation slows runoff from melting snow and rainstorms. Some of this captured water recharges groundwater or is released back into streams during dry weather. On lakes and seashores, wetlands buffer the effects of storms and wave motion, helping to reduce erosion.

Deltas depend on periodic flooding and deposition of *alluvial* materials (organic and non-organic sediments that are transported by rivers) to maintain their fertility. In essence, deltas are wetlands in a *primary state of succession*—that is, the colonizing plant species are not replaced by more mature forms over time. These plants—mainly aquatic grasses—produce food for birds, and their growth is governed by alternating cycles of high and low water levels. As with other wetlands, flooding also enriches the soil by adding nutrients, and sediments assist in trapping solar radiation. Deltas are also affected by changes in water temperatures from the break-up of ice. Overall, however, deltas have achieved a state of dynamic equilibrium with their surroundings. Flooding, erosion, and sedimentation all play vital roles in determining vegetational composition and overall productivity.

Estuaries are influenced in large part by constantly-changing water conditions. The freshwater outflow is relatively warm and rich in nutrients and sediments. In contrast, the deep oceanic waters are saline, well-oxygenated and low in temperature. Alternating flood and ebb tides mix the constituents of the distinct water masses. Like other aquatic ecosystems, estuaries contain a diverse array of plant and animal life. Resource inventories conducted in the St. Lawrence estuary past the confluence of the St. Lawrence and Saguenay Rivers have recorded a total of 274 species of invertebrates, 13 species of marine mammals, 83 other vertebrate species and 154 species of marine plants. Large cetaceans frequenting this portion of the estuary include the blue, fin and mink whales. Only the beluga, or white whale, is a permanent resident.

The Fraser estuary is even richer in its diversity, home to millions of crabs and some 80 species of fish, from tiny smelt to enormous sturgeon. In April and May, 300 million salmon fry travel down the Fraser River to feed in the shallow estuarian waters before moving out to sea. Ten million return to spawn, making the Fraser one of the largest salmon runs in the world. About a million waterfowl use the estuary as a stopover as they migrate along the Pacific flyway. Thousands of resident birds including hawks, eagles, loons, herons, gulls and sandhill cranes nest and feed in the estuary and nearby uplands. The marshes and mudflats of the Fraser delta and estuary provide an environment that is arguably one of Canada's most productive and valuable wildlife habitats.

Human Impacts On Ecosystems

The interface between land and water is an attractive place for all forms of life, including humans. Most of the towns and cities of Canada grew up along the banks of rivers, lakes and oceans as proximity to water meant a convenient drinking supply, bountiful fish and wildlife, and access to raw materials and manufactured products. But human settlement has invariably altered shorelines and natural water quality, upsetting the delicate balance so essential to the survival of aquatic ecosystems. In the struggle to compete with humans for water and its associated habitat, it is the endemic forms of life—the plants and animals—that most often lose.

Wetlands are among the richest and most productive of all ecosystems, yet their presence may impede urban and agricultural development. Consequently, they have been drained and filled, to be farmed or converted into subdivisions, industrial parks or airports. Environment Canada estimates that more than half of the original swamps and marshes of southern Canada have been lost, including 65 per cent of Atlantic coastal marshes, 70 per cent of the wetlands in southern Ontario and 71 per cent of the prairie wetlands. Along the lower Fraser River, the same processes that replenish the vast delta—flooding and sediment deposition——must be prevented if the sprawling city of Vancouver is to grow and prosper. Each year, about five million tonnes of sediment are dredged from the river channel to maintain adequate shipping lanes, and a system of dykes has been constructed to keep the Fraser in check. Dyking and landfilling alone have reduced the historic 20,000 hectares of estuarial wetlands by two-thirds. Domestic and industrial garbage disposal, toxic wastes, log booms and all-terrain vehicles, which tear up ground cover and disturb nesting sites, all threaten to irreversibly damage the dwindling habitat which remains.

World-wide, the picture is similar. In the United States, wetlands have been disappearing at the rate of 2,000 km^2 a year, and the harvesting of peat has virtually destroyed the bogs of Finland and Ireland. Fortunately, the importance of wetlands has now been recognized in many countries, including Canada. Some 17 sites covering more than 100,000 km^2 have been designated for protection in this country, and Canada and the United States, both signatories to the *North American Waterfowl Management Plan*, will attempt to purchase and restore some 15,000 km^2 of wetlands over the next 15 years. And an estuary management program for the Fraser, developed after eight years of study, proposes among other things that a compensation system for habitat restoration be adopted.

Canada's freshwater fishery is a magnificent and treasured resource that has long suffered in the face of advancing settlement. Although over-harvesting is undoubtedly one reason for the decline of the fishery nation-wide, habitat degradation has played an equal if not more important role. Over the years, a seemingly-endless number of human activities—dam building, road construction, logging, farming and domestic and industrial pollution—have altered the flow and

quality of rivers, streams and lakes. These waterbodies are as critical to the survival and growth of the fishery as soil is to the survival and growth of agriculture.

Dams were initially constructed to power gristmills and sawmills, and later to control floods and store water for irrigation and hydroelectric power generation. But dams also block fish passage, change the pattern of flow downstream and alter water temperatures. Most damaging appears to be the barrier that dams pose to adult fish migrating upstream to spawn. In some instances, fish ladders and even elevators have been constructed in an attempt to solve this problem.

Land-based activities can have a pronounced impact on fish habitat. Silt from logging and mining operations, road building and agricultural runoff plugs the spaces in spawning gravel and smothers fish eggs and fry. As well, siltation affects the production of insect larvae and other aquatic invertebrates on which fish depend for food. Contour plowing and other improved tillage methods have curbed this impact somewhat, yet topsoil losses from water erosion remain a major problem for farmers across Canada. Selective cutting and reforestation, two practices that would reduce stream sedimentation, have still not been widely adopted by the forest industry.

Fish habitat is affected by nutrients and biodegradable organic materials from farm fields, feedlots, municipal sewage and industrial wastes. These substances can lower the dissolved oxygen content of receiving waters to such an extent that fish suffocate. In the longer term, they can accelerate eutrophication of lakes and rivers. While eutrophication does not affect total fish production, it does cause changes to the aquatic environment which alter species composition.

The most serious threat to fish habitat comes from atmospheric pollutants that return to earth as acid precipitation. Many of the streams in eastern Canada have been acidified to the point they no longer support most aquatic life, as have thousands of lakes in Ontario and Québec. It is unlikely that acid water *per se* kills fish, except in cases of 'acid shock' where melting snow discharges unusually high amounts of acids into the aquatic environment. Rather, it appears to trigger changes in aquatic ecosystems. We know, for example, that acid lakes have elevated levels of mercury, lead, copper, cadmium and aluminum. Aluminum is absorbed by fish and interferes with the exchange of salts. Moreover, plaques of aluminum hydroxide may form on the gills, reducing blood oxygenation and causing eventual suffocation. Acidity reduces calcium absorption by crayfish, causing noticeably thinner shells, and diminishes species diversity of phytoplankton, the primary food source for all consumers in aquatic food chains.

Stream sedimentation, eutrophication and acidification are all examples of how human activity can upset the balance of life in aquatic ecosystems. In most instances, the impacts of our actions are unintended, yet we show a surprising ignorance of water's carrying capacity and its interconnectedness to land and air

through the hydrologic cycle. The investment of public and private funds in habitat restoration indicates an increased sensitivity toward aquatic ecosystems, but it also typifies our 'react and cure' mentality. In the long term, it may be wiser (and less expensive) to prevent habitat destruction by recognizing nature's patterns and altering our practices to fit these patterns.

The St. Lawrence Belugas: A Case Study

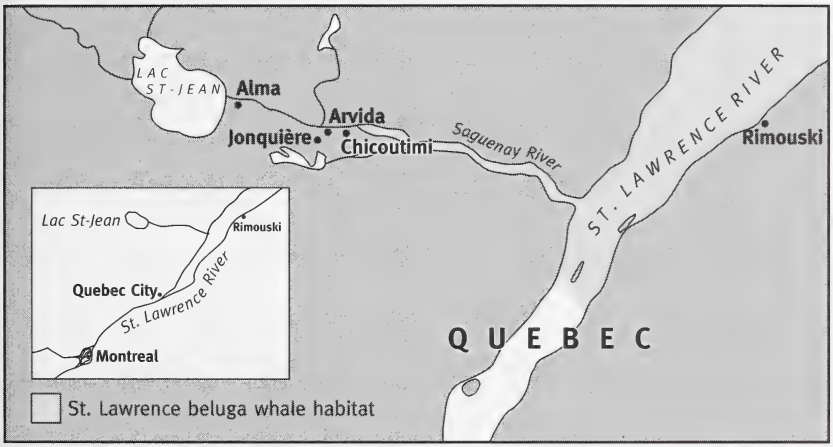


Figure 8: *St. Lawrence Beluga Habitat–Adapted to the arctic-like conditions of the Saguenay Fjord and St. Lawrence Estuary, the beluga faces extinction from an onslaught of toxic chemicals.*

In the late 1980s Pierre Béland, a Canadian marine ecologist, attracted national attention with his research on beluga whales in the St. Lawrence River. In these massive creatures, he has discovered a poignant symbol that in Canada has come to represent the tragedy of an ecosystem gone awry—for people as well as for wildlife.

Belugas are toothed whales found in the Arctic Ocean and adjacent waters of northern Europe, Russia, Alaska and Canada. Among the smallest of whale species (adults reach a length of about 4.5 metres), belugas are well suited to arctic conditions, where their albino skins make them virtually indistinguishable from chunks of floating ice. Opportunistic feeders on various fish and aquatic invertebrates, the whales inhabit deep coastal waters during the winter and move into estuaries in summer. World-wide, their numbers are estimated to be between 30,000 and 60,000.

The St. Lawrence beluga population probably established itself some 10,000 years ago when the region now comprising the St. Lawrence and Saguenay Rivers was

an inland sea. This sea vanished as the land slowly rose following the retreat of the glaciers, and was replaced by fresh water from the Great Lakes filling the deep Laurentian channel. Other marine mammals withdrew eastward to the Arctic, but the belugas, adapted to estuaries, remained behind. The St. Lawrence population is believed to be genetically different from other belugas, and the unique, arctic-like conditions of the estuary support the whale herd year-round.

As with the humpback and blue whales, the belugas were exploited for their hides and oils. Commercial hunts, begun by Basques in the latter part of the 16th century, continued until the early 1900s. Three decades later, local fishermen, believing the whales were depleting fish stocks, convinced the Québec government to authorize a bounty on belugas. Between 1932 and 1938, 2,235 animals were killed. Although large-scale hunting was discontinued in the 1950s, the number of St. Lawrence belugas has steadily declined. At the turn of this century, the population was estimated at 5,000. About 1,200 existed in the early 1960s. Today, only 450 to 500 remain, despite being protected as an endangered species. Several reasons have been suggested for the demise of the belugas—overexploitation, dredging of the St. Lawrence, and the impact of hydroelectric dams. A fourth reason has more recently emerged: the belugas are the victims of toxic substances which have contaminated their habitat.

The fact that toxic substances are widely spread throughout the environment is now well-known. Some, like pesticides, are carried in farm runoff or drift into waterbodies after they are sprayed; some are directly discharged in industrial wastewaters; and some are leached from landfill sites into neighboring streams and aquifers. Although toxic substances pose a significant threat to the health of organisms and humans, they are rarely present in water in high concentrations. Why is it, then, that they are so dangerous?

The answer, in part, has to do with the nature of feeding relationships in ecosystems. Animals feed on plants and are, in turn, fed upon by other animals. The sequence of feeding can be illustrated by a food chain. *For example, phytoplankton (microscopic plants) are eaten by small aquatic animals, which are eaten by fish, which are eaten by seals. In reality, feeding sequences are more complex, because one organism may serve as a food source for several others (fish may be eaten by birds, polar bears or whales). The interconnecting food chains in an ecosystem constitute a* food web.

Feeding is the way most organisms acquire energy (plants that make their own food supply are the exception). Energy dissipates through food webs because a portion of the energy is used by the organisms for their ongoing life functions. Thus, an animal must always consume a greater number of organisms (plants or other animals) directly below it in the food web. The actual numbers depend on the amount of energy that can be obtained from the food source.

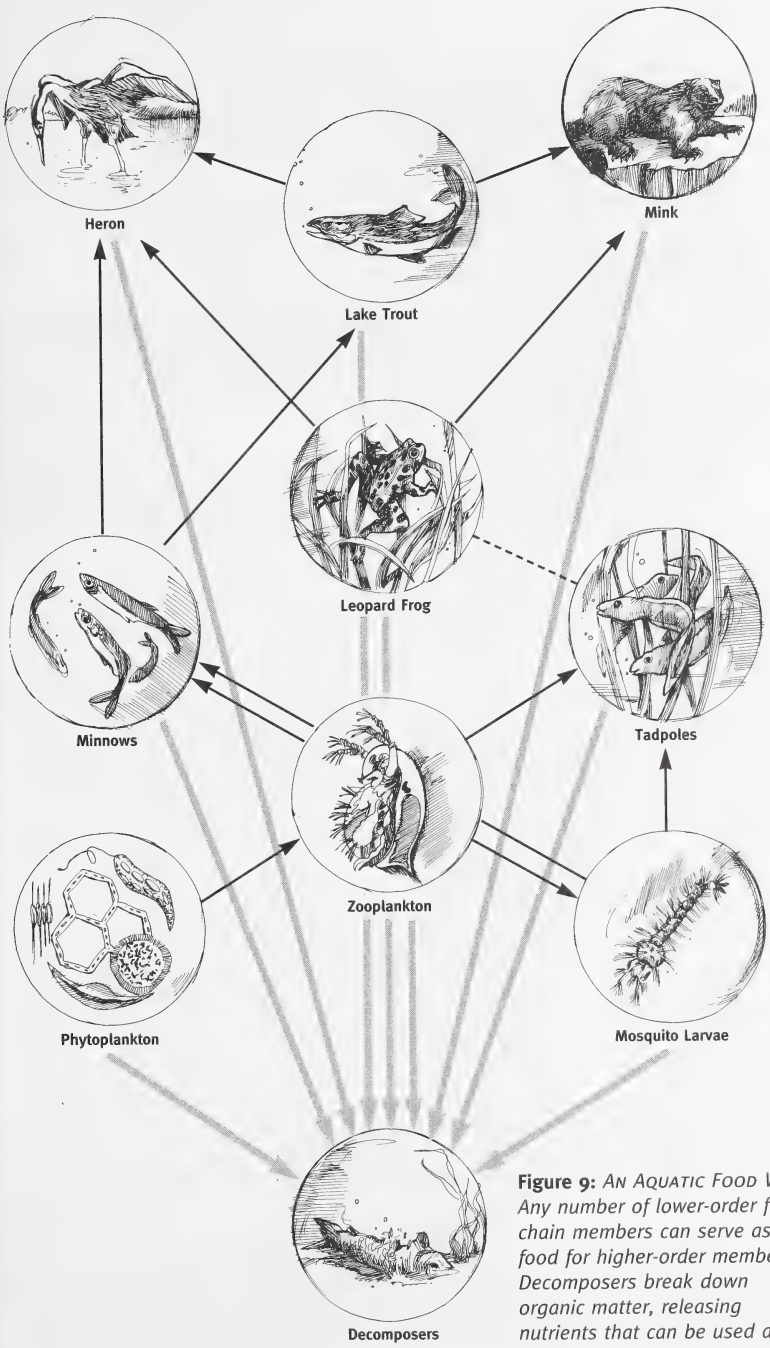


Figure 9: *An Aquatic Food Web– Any number of lower-order food chain members can serve as food for higher-order members. Decomposers break down organic matter, releasing nutrients that can be used again.*

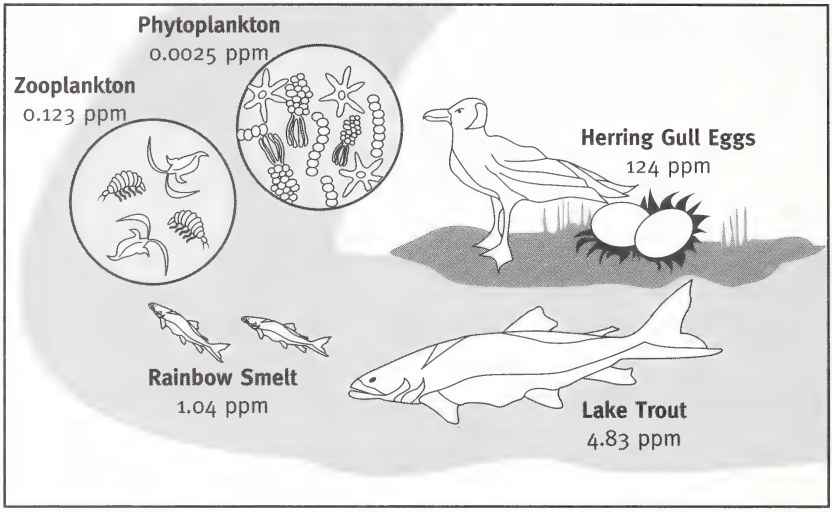


Figure 10: *Bioaccumulation and Biomagnification—The bioaccumulation of toxic substances in a food web can magnify the low concentrations found in phytoplankton by a factor of 250,000 or more, to dangerous levels in fish and birds.*

Toxic substances, because they are prevalent in the water, are incorporated into aquatic plant life. Many of these substances are also persistent, *that is, they do not easily break down and therefore become more highly concentrated as they pass through the food web. This phenomenon, known as* bioaccumulation *or* biomagnification, *means levels of toxic substances in the bodies of some predatory birds and mammals can be 100,000 to one million times higher than in the surrounding water environment.*

The toxic substances that are of major concern to ecosystems are organochlorines, *a group of synthetic organic molecules that include polychlorinated biphenyls (PCBs), dioxins, and pesticides such as DDT, chlordane, mirex and toxophane. Although organochlorines are not very soluble in water, they dissolve readily in fats and oils and can therefore be easily stored in fatty tissue. DDT, widely used until its restriction in the early 1970s, is thought to be responsible for the near extinction of peregrine falcons and brown pelicans because it interferes with the calcification process, making egg-shells thinner and more fragile. PCBs have become widely dispersed in the environment and have been linked to reproductive failures, epidermal disorders and birth defects in mammals, including humans.*

Whales, on the other hand, were thought to be immune from toxics like DDT and PCBs because these chemicals are stored in the blubber, a tissue considered to be relatively inert. Studies on the St. Lawrence belugas have revealed, however, that while the blubber holds most of the pollutant burden, toxics show up in other

tissues. These studies also have shown that male belugas are more contaminated than females, and that young belugas are the most contaminated of all. This is because females have a mechanism for unloading organochlorines. During pregnancy, small amounts of the contaminants are transferred to the foetus through the placenta. After birth, much larger amounts are passed from the mother to her young through breast milk, a fluid very rich in fats. Finally, the studies have confirmed that the St. Lawrence fish and invertebrates on which the belugas feed are contaminated, and although levels in fish are lower than would constitute a health hazard for human consumption, the bioaccumulative effects on the whales are, in some cases, lethal.

As damaging as PCBs and DDT residues are to the belugas, there are other chemicals that may have more serious effects. The Saguenay Fjord, summer habitat of the St. Lawrence population, is also home to one of the largest aluminum-producing complexes in the world. Over the years, aluminum smelters have released large amounts of mercury, fluorines and polycyclic aromatic hydrocarbons (PAHs) into the environment. One PAH compound, benzo(a)pyrene, or BaP, has entered the Saguenay River through industrial wastewaters and fallout from smelter plant stacks.

In the early 1980s, workers at the Alcan smelter in Chicoutimi, Québec, were found to have an abnormally high incidence of bladder cancer. Subsequent laboratory studies on fish showed that BaP is broken down within organisms into metabolites which then bond to proteins and DNA, the genetic code. This evidence suggested a causal relationship between BaP and cancer, something supported in the scientific literature over the last few years. Furthermore, BaPs have been found in the sediments of the Saguenay, in blue mussels of the St. Lawrence at the Saguenay mouth and in the brain cells of beluga whales.

PCBs, DDT and BaP are but three of twenty-five toxic chemicals and metals that have been discovered so far in the blubber, livers, kidneys and brains of the St. Lawrence belugas, making them probably the most contaminated mammals known on earth. Since 1972, dozens of autopsies on dead belugas have revealed a frightening array of abnormalities never before reported in toothed whales: bladder cancer, rupture of the pulmonary artery, fibrosis of the spleen and herpes-like skin lesions. Two very young belugas were particularly striking cases. The first one, a two-and-one-half-year-old, had a perforated gastric ulcer, pneumonia, hepatitis and dermatitis. The second, aged 1.5 years, had encephalitis, pneumonia and dermatitis. A third animal, a young adult female 14 years old, had a generalized bacterial infection. The condition of all three animals strongly suggests that their immune system was suppressed and unable to mount an adequate defence against disease-causing organisms.

The St. Lawrence belugas face an uncertain future. Birth rates are thought to be about half those in other arctic populations, and the youngest members of the herd are dying at a faster rate than the adults. If the number of reproducing

females, now estimated to be 140, drops substantially, the numbers of calves produced each year may become too small to ensure the survival of the population.

In 1988, the governments of Canada and Québec signed the Canada-Québec Convention on the St. Lawrence River, *committing $110 million over the next five years to protect, conserve and restore the river. The Convention contains four components: $20 million to protect endangered species and the creation of a marine park at the confluence of the St. Lawrence and Saguenay rivers; $14 million to assess sources and pathways of toxic substances entering the Québec section of the St. Lawrence; $21 million to rehabilitate wetlands affected by pollution along the river and to clean up federal port facilities; and $55 million to develop pollution abatement technologies on a cost-shared basis with industry, provincial and federal agencies, universities and other non-government institutions.*

The plight of the St. Lawrence belugas illustrates the degree to which human activity can affect aquatic ecosystems. In this instance, the Great Lakes and St. Lawrence River systems suffered from decades of abuse before any action was taken to restore them. On a more encouraging note, governments at all levels now appear to be more prepared to spend the funds necessary to control pollution and mitigate environmental damage to habitats. This reaction is due in no small part to a growing awareness among the public that ecosystems and the biosphere must be protected.

In the past, we have tended to view our impacts on ecosystems as isolated instances of environmental degradation which could be corrected by technology. What is becoming apparent, however, is that the damage to one of its parts affects the biosphere as a whole because water does not and cannot exist in isolation from the global processes governing its distribution. A case in point is toxic chemicals. Their introduction into a river system may affect the suitability of that river to support aquatic life, but the transport of these chemicals by rivers into the oceans results in their dispersal around the world. Because of the vastness of the oceans, small amounts of toxic chemicals from one location may seem insignificant, but the cumulative effects of chemicals from many locations may indeed be very significant. Thus, the net effect is a poisoning of the lifeblood and a threat to the total life-support system.

Study Four: Water for Human Needs

Photo Courtesy City of Toronto Archives, James 1122A

Toronto Harbour near the turn of the century: uncontrolled pollution turned waterways near large settlements into virtual cesspools.

Humans have depended on water since the beginning of civilization. Our ancestors built communities along rivers and lakes to assure enough water for domestic and agricultural needs. Evidence confirms irrigation was used extensively by the Sumerians and Egyptians about 3500 B.C., although it was likely practiced some 1,500 years earlier. Water was also the vehicle for trade among the Egyptians and Phoenicians, and the open seas allowed exploration and colonization of the New World by the English, French and Spanish. Countless wars were fought to protect vital straits and transportation routes because those countries that controlled navigation also controlled commerce and trade.

The other time-honoured use of water was the disposal of human sewage. Archaeologists have found masonry sewers dating back to 3750 B.C. and there were even water-flushed latrines in the Minoan culture on Crete from 2500 to 1400 B.C. Although our water-using practices and technologies have changed over time, our dependency on water for irrigation, navigation and waste disposal remains.

In Canada, the first users of water were the native societies inhabiting our country after the retreat of glaciers. These societies depended on water primarily for food and transportation. Fish was the staple diet of tribes along the West Coast, the Great Lakes and the Eastern Seaboard, and several cultures evolved specialized techniques for fishing, including the use of nets and *weirs* (submerged logs). Native diets were supplemented by moose, deer and fur-bearing mammals that inhabited the marshlands and river banks. Traditional hunting and fishing patterns,

so vital to these early inhabitants, are still found today among the aboriginal people in the northern areas of Canada.

When the Europeans arrived in Canada, they too relied on water for transportation. Four key lakes—Huron, Superior, Winnipeg and Athabasca—were the hubs of an interconnected system of waterways through which furs could be harvested and then exported to markets across the Atlantic. So lucrative was the trade that the North West Company partners earned £1,185,800 in net profits during the first 15 years of the 19th century. While the fur trade flourished because of the high demand for beaver hats in Europe, it also stimulated the exploration of Canada's vast interior.

As settlement progressed, water was vital to agricultural and industrial growth. Rivers powered the grist mills and sawmills along the St. Lawrence and Annapolis valleys of Upper Canada, facilitating the production and export of grain and lumber, the two economic staples of the region. Tanneries, breweries, forges and textile mills used water primarily as a source of energy to drive their machinery. In the west, agricultural development depended on the irrigation of arid lands, and large-scale storage and distribution systems were constructed to facilitate the delivery of water to farm families.

Around the beginning of the 20th century, industry began to diversify. Mining became an important activity, and with it smelting and refining. Pulp and paper manufacture also began about this time. These industries differed from those of the previous half-century in the ways they used water. Some used heat-intensive production processes requiring water for cooling. Others used water in chemical reactions or extraction processes. The post-war period saw expansion of these industries and the growth of new ones such as petroleum refining and petrochemical production.

The power of falling water has been known and used for centuries, but the technology to harness this power and generate electricity was not perfected until the late 1880s. In Canada, power was first used to light Ottawa sawmills, and before 1890 homes in a number of Ontario and Québec towns were enjoying electricity. Niagara Falls was harnessed in 1915, and other hydroelectric facilities were constructed along the St. Lawrence River, fueling the growth of both Toronto and Montreal. Adaptation of electricity to industrial processes and advances in the techniques of power transmission fostered a five-fold increase in Canada's hydroelectric generating capacity between 1900 and 1910. Indeed, proximity to cheap power was one of the reasons Canadian industries were able to flourish, particularly in the densely-populated eastern part of Canada.

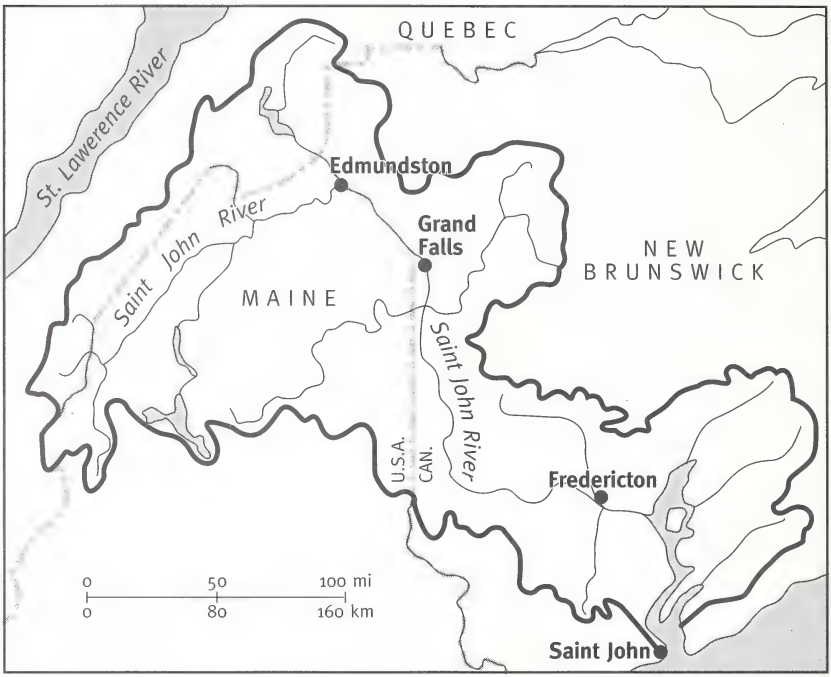
While water serves an important role in development, no society can survive unless its people have enough water to meet their domestic needs. Early cultures relied on the natural quality of wells, streams and lakes—and the exhaustion or pollution of local supplies became impediments to growth. The Romans solved the problem

by building aqueducts to bring water to their cities from neighboring hills. The modern equivalent of this technology took some time to develop, and prior to the beginning of the 20th century, Canadian cities lacked water-distribution systems. In Ottawa, water was peddled by water carriers who transported it in wooden barrels or *carets*. The first public waterworks system was constructed in 1873 in Saint John, New Brunswick. Similar systems were installed in Toronto, Halifax and Montreal during the next two decades. By 1981, more than 2,500 communities in Canada had water-supply systems, although many rural areas still depended on groundwater.

Rivers are the most accessible source of water for human consumption but they are also convenient conduits for human sewage. Up to 125 years ago, we did not understand that bacterial contamination of municipal water supplies was linked to the widespread incidence of cholera, typhoid and dysentery. Such a connection was finally established following a European cholera epidemic which claimed some 250,000 lives between 1845 and 1849. It took another 50 years to discover that disinfection with chlorine was an effective way to control water-borne pathogens. Today, virtually all Canadian cities filter and disinfect raw water supplies to remove sediments and pathogens.

The preceding discussion illustrates that the economic and social evolution of Canada has been contingent on the availability of abundant water supplies. But development extracts a price when it is not accompanied by adequate safeguards. As the following case study illustrates, the uncontrolled exploitation of natural resources can cause innumerable problems, particularly when there is little understanding of the interconnections between population growth and the water environment.

The Saint John River Basin: A Case Study



Adapted from *A Primer on Freshwater*, Environment Canada, 1991

Figure 11: *Saint John River Basin–One of the largest river systems in the Maritimes, the Saint John River drains portions of Maine, Quebec and New Brunswick before emptying into the Bay of Fundy.*

The Saint John River is an important source of water for the western and southern portion of New Brunswick. Since the end of World War II, the river and its tributaries have been the focus of intense competition among forestry, agricultural and hydroelectric power interests. The river system is also an important breeding area for Atlantic salmon and other commercial fish. It is also used for recreation and for the disposal of wastes from the area's pulp and paper and food-processing industries.

The Saint John Basin drains some 55,000 km² of Maine, Québec and New Brunswick, making it one of the largest watersheds in eastern North America. From its headwaters at Little Saint John Lake on the Maine-Québec border, the river travels some 700 kilometres before emptying into the Bay of Fundy on the Atlantic coast. Slightly over half the area drained by the Saint John lies in New Brunswick. Although the timing and magnitude of river flows varies from year to year, high

streamflows usually occur in April and May. Typically, there are two low-flow periods—late summer and mid-winter.

Prior to the arrival of Europeans, the Saint John was used by the Micmacs for fishing and transportation. By the end of the 17th century, the Acadians, attracted by the rich farmlands of the river's floodplain, began to settle in the region between Fredericton and Saint John. In addition to domestic and agricultural uses, the river provided the power to operate local grist mills.

Following the fall of Acadia in 1758, French settlers were replaced by New Englanders, but the region did not experience very much growth until after the American War of Independence, when United Empire Loyalists swelled the population to 35,000. Over the next 150 years, natural population increases and immigration from the British Isles multiplied the region's number of inhabitants about 40 times.

Forestry was the first major economic activity in the Saint John Basin. The French, and later the English, harvested New Brunswick white pine for sailing ship spars and masts, and the river served as a route for steam drivers who transported logs downstream to the sawmills. Hydroelectric power generation was begun in 1904 with the construction of a station near Woodstock. Other plants on the river's tributaries soon followed; the main part of the Saint John River was first dammed at Grand Falls in 1928.

In the post-World-War-II years, the Saint John River Basin experienced the same industrial and urban growth as the rest of North America. Between 1951 and 1971, the population of the basin increased from 231,000 to 299,000. With urbanization came the attendant problems of water pollution, exacerbated by the virtual lack of sewage treatment. During this period, the forest industry shifted its operation from sawmills to pulp and paper production. The change resulted in more highly-mechanized forestry practices, including clear-cutting and extensive road networks, both of which accelerated soil erosion and stream sedimentation. Pulp and paper mills, large users of water, added significantly to river pollution. As with New Brunswick cities, the mills had no treatment facilities and the organic loading of these wastes was comparable to the loading from a city of several million people.

Water quality problems from urban and industrial wastes were often compounded by hydroelectric dams. The Beechwood and Mactaquac Dams on the main stem of the Saint John, and the Tobique Dam at the mouth of a major tributary, altered the river upstream from Fredericton from a fast-flowing stream to one with 'headponds' which trapped polluted water, lowering dissolved oxygen levels and degrading fish habitat.

Potato farming has long been the mainstay of New Brunswick agriculture. Following World War II, cropland was consolidated into larger farms. To maximize

their yields, local growers did not practice crop rotation, which would have stabilized the soil, and began to use fertilizers and pesticides more extensively. This shift in agricultural methods exacerbated the problem of stream sedimentation, and added chemical pollutants from surface runoff to the river system. During the late 1950s, several companies built food-processing plants in the basin, including those that converted raw potatoes into more marketable and popular forms—french fries and potato chips. Food-processing wastes, largely untreated, further contributed to a worsening of water quality along the middle reaches of the Saint John River between Florenceville and Fredericton.

The Atlantic salmon, once the most valuable fishery in the Saint John Basin, declined in the 1950s and again in the late 1960s. Between 1971 and 1980, the New Brunswick commercial salmon fishery was closed, and despite stringent quotas and restrictions imposed when the fishery was opened again in 1981, fewer and fewer fish were being caught. While the reasons for this are still not completely understood, the decline in the 1950s corresponds to the time when DDT was indiscriminately sprayed on forests to control the spruce budworm, and the Tobique and Beechwood Dams were constructed.

Despite a steady deterioration in water quality and fish habitat in the Saint John Basin, little was done to acknowledge the damage until 1960. In a widely-publicized water-quality survey, the federal department of Health and Welfare described the condition of the Saint John River between Edmundston and Grand Falls as 'grossly polluted'. Dissolved oxygen levels along this reach averaged well below 5 mg/L, the accepted standard for fish, with some readings at zero, and fish kills were observed and reported. In 1964, dissolved oxygen levels in the same reach were recorded at levels between 1.7 and 0.5 mg/L, and pulp and paper wastes (ammonia and nitrates) were detected well downstream from Woodstock. A 1968 survey stated that the "massive discharge of organic wastes at Edmunston has a marked effect on water quality in the [Saint John] river for about 175 miles downstream". This survey also noted oxygen deficiencies in the lower depths of headponds, and amounts of fecal coliforms which sometimes exceeded acceptable limits for drinking water and recreation.

By 1970, developmental pressures in the Saint John River Basin had so severely degraded water quality that remedial action became imperative. Two years later, a major cleanup was begun under the auspices of the International Saint John Water Quality Committee, a group composed of representatives from each of the Basin's jurisdictions. This committee, working co-operatively with local government authorities, has been able to make considerable headway in curbing municipal and industrial pollution. Over a twelve-year period, point-source loadings of BOD have been reduced by 88 per cent and suspended solids by 82 per cent. In 1972, only 13 of the Basin's municipalities had sewage treatment; in 1982, all but three had sewage treatment. Some progress has also been made toward the elimination of non-point-source pollutants. In particular, pesticides are now more carefully regulated and farmers are better educated about their use and handling.

Another long-term concern of the Water Quality Committee has been the restoration of the Atlantic salmon fishery, and progress has been evident in this area as well. In New Brunswick, fish passage structures were designed at the Mactaquac, Beechwood and Tobique Dams to assist migration of the salmon to spawning grounds. The New Brunswick Electric Power Commission also built a hatchery downstream of the Mactaquac Dam to compensate for the loss of salmon production during the dam's construction. This action is illustrative of government-industry co-operation to mitigate resource losses. In Maine, the Tinker Dam on the Aroostook River is presently a barrier to fish migration. At one time, the Aroostook was considered one of the best Atlantic salmon fisheries in North America. To restore the fishery, the Atlantic Salmon for Northern Maine Inc., an organization which promotes and co-ordinates local restoration efforts, is lobbying for the construction of a fishway around Tinker Dam. The group is also promoting stocking efforts which resumed in 1978 for the first time in seventeen years.

There are still problems to overcome. If the Castle Hill Dam on the Aroostook River is built, it would inundate 16 kilometres of the river valley and flood over 2,000 hectares of land. A 1956 study by the Maine Department of Inland Fisheries and Game estimated that construction of the dam would reduce salmon spawning and rearing areas in the Aroostook by one-third. Other dams are also under consideration. A proposed open-pit mine at Ashland, Maine, could contaminate the Aroostook with heavy metals.

The International Committee on Water Quality continues to monitor the river and to pursue its goal of making the Saint John and its tributaries fishable and swimmable. On February 20, 1984, the governments of the United States and Canada renewed the Committee's mandate for an indefinite period. Continued co-operation with governments at all levels will be needed to ensure that the Saint John River does not return to the conditions experienced fifteen years ago.

Current Patterns of Use and Technology

Human uses of water can be categorized as *withdrawal* or *instream uses* and as *consumptive* or *non-consumptive*.

Withdrawal uses are those which remove water from a source (e.g. a lake, river or aquifer), consume a portion, and return what is left over to the water system, although not necessarily to the place it was originally withdrawn. Returned water often contains contaminants which are added to water during use. Water used for domestic purposes, for example, contains human and household wastes. Municipal, domestic and industrial uses, and the use of water for thermal and nuclear power generation, irrigation and stockwatering fall into the category of withdrawal uses. Instream uses are those which use water in its natural state and include hydroelectric power generation, navigation, water-based recreation and waste

disposal. In general, instream uses are non-consumptive and non-polluting. The major exception is waste disposal, an instream use that is also consumptive.

Consumption, in the broadest sense, removes water from circulation so that it is unavailable for further use. Drinking a glass of water, applying water to crops and using water as an ingredient in industrial processing are all examples of consumption. The actual amount of consumption varies among withdrawal uses, depending on how much water is withdrawn and returned. The terms consumptive and non-consumptive are somewhat artificial because water is almost never lost to the hydrologic cycle. (What happens to the water you drink?) Nevertheless, they are useful in evaluating the overall impact of water-using activities on the available supply.

Canadians are heavy users of water, second only to the United States on a per capita basis. Although actual per capita figures are difficult to determine, it is likely that roughly 5,000 litres of water each day are required to satisfy the domestic, municipal, industrial and agricultural demands of each Canadian. Add to this the water used for energy production and the total is even higher. We might expect that such figures are a reflection of our water wealth. But other countries, equally well-endowed with water, have not been able to achieve the standard of living that water can afford. The difference, in part, has been our ability to develop technologies that diversify and expand the use of water. While some of these technologies have been developed specifically to make water use more efficient and to reduce the demand of the available supply, others have actually encouraged greater consumption of water by lowering the cost of production to the extent that water, perhaps the cheapest of all natural resources, can be used ever more profitably. Let us look, therefore, at how we are presently using water consumptively and how the choice of technology influences both our lifestyle and our environmental quality.

Municipal and Domestic Uses

Domestic uses are those we usually associate with the home—bathing, cooking, clothes-washing and drinking—as well as sanitation (toilets) and the watering of lawns and gardens. Municipalities, in addition to supplying homes, commercial districts and small industries, use water for street-cleaning and firefighting and in public facilities such as swimming pools, ice arenas, schools and parks. In most communities, treated water is conveyed through a distribution system of water mains and pumping systems. A parallel system collects sewage from homes, offices, public buildings and small industries.

On average, each Canadian uses about 450 litres (about 100 gallons) of water each day for domestic purposes. (This figure is based on the average per capita consumption of urban dwellers, and it is likely that rural households use considerably less.) For the average urban dweller, 43 per cent of daily use goes

down the toilet. Bathing and showers account for 21 per cent and an additional ten per cent is used when washing clothes and dishes. Only five per cent of domestic water supplies are used for drinking and cooking. The remaining four per cent is for outside use, although water use can increase dramatically when we water our lawns during the summer. By comparison, daily rates in Sweden and the U.K. are 200 litres/day, in Beijing 145 litres/day, and in many parts of Africa and South America as little as 12 litres/day. Water is also very inexpensive in Canada. While prices vary across the country, studies have determined that we pay, on average, about 36¢ per 1,000 litres of water. Consumers in the United States pay an average of 42¢ per 1,000 litres, in the U.K 66¢, and in Australia, $1.47. The high per capita use of water by Canadians also means a high per capita production of sewage, since as much as 80 per cent of water used in the home ends up in sewage treatment plants. In many Canadian communities, residents pay a combined charge for water and sewer based on a *flat rate* (a set monthly or bi-monthly fee, regardless of the amount of water used) or a *metered rate* (based on actual consumption). Rates in Canada range from a low of $1.70 per month to $25 or more per month, depending on the community. In contrast, many people in Third-World countries have no sewage systems at all, yet it is possible to dispose of human wastes inexpensively and safely. In the Philippines, for example, villagers use 'water-seal' toilets which require only a litre of water to flush. Designed much like a kitchen sink trap, these toilets empty into a septic field and are relocated once the field has been filled.

Irrigation

Irrigation is widely used throughout the world to supplement rainfall and to enhance agricultural productivity. China irrigates over 76 million hectares (almost 70 per cent of all cultivated land in the country), or nearly a third of the world's total. The United States, third behind India, irrigates about 21 million hectares, or some ten per cent of its cultivated land. Canada ranks well down the list, with about 630,000 hectares (1.55 million acres) under irrigation, or about one per cent of the total cultivated acreage nation-wide. But this is heavily concentrated in a few areas. Over 60 per cent of Canada's irrigated land is in southern Alberta. British Columbia ranks second with 15 per cent, mainly in the Okanagan Valley. Irrigation is also practiced in Saskatchewan, Ontario and Québec, and to a lesser extent in Manitoba and the Maritimes.

The simplest and least expensive way to irrigate, the *flood method*, channels water by gravity or siphon from a stream to a series of ditches between crop rows. Used primarily in China and southeast Asia to grow rice, flood irrigation is labour-intensive and impractical on sloping land. *Sprinkler irrigation*, a more popular method with Canadian and American farmers, applies water with wheel-move systems or centre pivots, which form the 'circles of green' punctuating aerial views of some of Canada's western farmlands. The sprinkler method is both capital- and energy-intensive (it requires fuel to operate pumps) and can lose large amounts of

water by evaporation on dry, windy days. Nevertheless, it has greatly facilitated irrigation development in this country because water can be applied to a relatively large area with little labour. A third method, *drip* or *trickle irrigation*, is used primarily in greenhouses and orchards. Trickle lines are located between crop rows and emitters (small devices that allow the escape of water drops) are placed at various intervals, depending on soil type and plant spacing. Trickle systems are highly efficient with little or no evaporative losses and the plant receives, through continuous application, exactly enough moisture. Because of their design and cost, trickle systems are not practical for grain and forage crops.

Not all the water withdrawn from a river for irrigation is applied directly to the crop. Some evaporates from storage or canals; some may be lost through seepage (the lateral movement of water through canal banks) or taken up by aquatic plants growing in canals, and some may end up in sloughs or ponds as *spill water*. These factors partly account for irrigation's high consumption rate—61 per cent of all water consumption in Canada. Irrigation can also adversely affect water quality when salts, fertilizers, pesticides and soil particles are contained in return flows.

Although Canada requires far less irrigation because of its temperate climate, the technology and economics of irrigation are highly attractive. While irrigation in many developing countries is vital to the production of a basic food supply, western nations like Canada and the United States have used irrigation to grow commodities that can be exported or used domestically to enhance our standard of living. Feed crops under irrigation, for example, are used primarily for raising cattle, and fruits, vegetables, oilseeds and cotton would be considered luxury items to Third-World subsistence farmers. Beyond this, some American and Canadian irrigators have often been able to obtain water at low prices because of public subsidies for its storage and delivery. Alberta farmers, for example, pay a flat rate of between $3 and $12/acre, a bargain compared with the cost of fuel and agricultural chemicals. Their counterparts in British Columbia, on the other hand, pay between $50 and $75/acre. The difference is related in part to the availability of water and the amount of financial assistance from provincial governments.

Industrial Uses

Water has a wide range of industrial applications: it is used as a raw material, a coolant, a solvent and a source of energy. Industrial requirements for water vary greatly in terms of quantity and quality, and many industries have evolved sophisticated technologies for using water efficiently.

The mining industry uses water to separate ores from surrounding materials, to cool drill bits and other excavating equipment, to wash ores at various stages of the production process and to carry away mill tailings (the mixture of water and ore left after processing). Metal mining produces many pollutants, including arsenic, copper, lead, nickel, zinc, radium 226 and acids. Seepage from tailing

ponds and abandoned mines can contaminate surface and groundwater supplies, affecting the health of people who use them for drinking water.

The petroleum industry uses a number of technologies to extract and process oil that cannot be recovered by conventional drilling. The *deep well injection* method displaces underground oil with water pumped into wells under pressure. A similar technique, *steam injection*, reduces the viscosity of heavy oil so that it will flow to the surface. The extraction and processing of bitumen poses special problems because oil is embedded in sand. The *fireflood* method ignites sub-surface deposits with burners or chemicals. Oxygen and water are then injected, and the resulting steam liquifies and separates the embedded oil so that it can be pumped from the ground. Surface deposits of bitumen require yet another process. Here, bitumen is mixed with hot water and other substances in a huge revolving drum. The resulting slurry is screened to remove sand and other debris, then conveyed to separation tanks where oil can be skimmed from the top. Water is reclaimed, whenever possible, and used again. The injection methods, however, are totally consumptive, as water cannot be recovered. To date, enhanced oil recovery represents only a fraction of current oil production, and the use of water is relatively small. Full development, contingent on investment and oil prices, could increase the use of water considerably.

Water is also used extensively by the chemical and petrochemical industries to manufacture paints, inks, acids and alkalis, fertilizers, ethylene, methanol and styrene (a main ingredient of plastics and resins); to remove hydrogen sulfide from sour gas, and to 'cook' wood chips during pulp and paper manufacture. Because water in these instances comes into contact with the product or by-product, it usually contains contaminants which, if not removed, can cause serious pollution problems. Pulp wastewaters, for example, are high in BOD and dissolved solids that may affect the colour and odour of receiving waters. The pulp and paper industry also uses a bleaching process to make the paper white. In the past, bleaching was done with chlorine, using mercury as a catalyst. Mercury is no longer used by most pulp and paper industries because of its toxicity in the environment. *Chlor-alkali* or *kraft-bleaching* methods still use chlorine, however, and small amounts of dioxin can be present in pulp effluents.

Of all industrial uses, cooling requires the greatest volume of water, and the largest users of water for cooling are thermalelectric power plants (some gas plants and oil refineries also use water for cooling). The process itself removes waste heat from condensers that convert steam back to liquid form. Water is ideally suited for this purpose because it can absorb large amounts of heat without a great rise in temperature. Of the three types of cooling systems presently used in Canada, the most water-intensive is the once-though system, so-called because water taken from a river or lake passes through a condenser only once before being returned. Water leaving the condensers is several degrees warmer, and in once-through cooling systems, this warm water can cause thermal pollution and serious damage

to aquatic life. For this reason, once-through systems are usually restricted to fairly large rivers, where flows can dissipate the heat quickly.

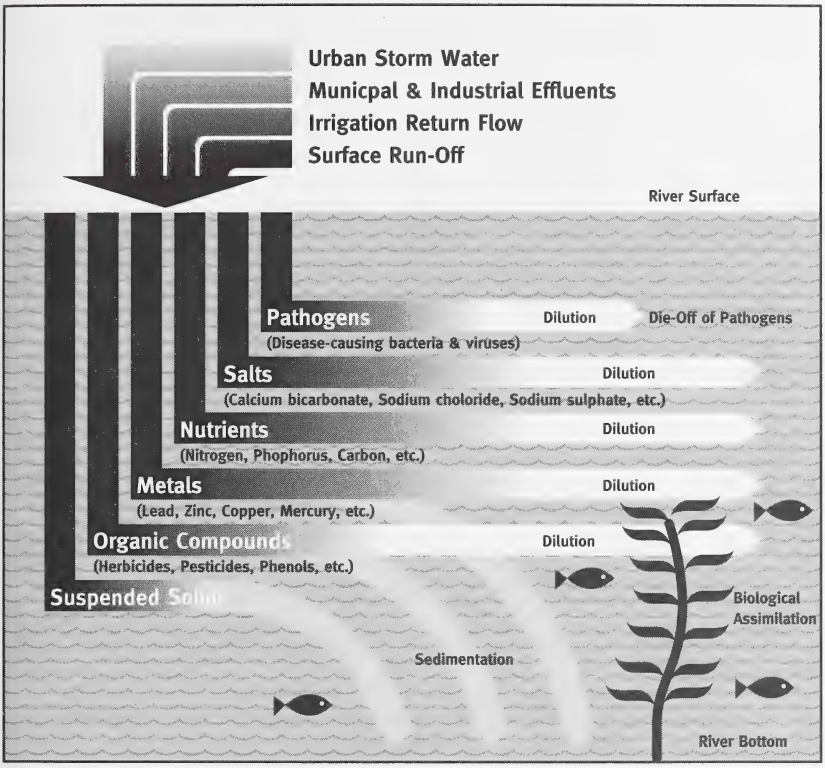
Thermalelectric plants located some distance from a river or lake use cooling ponds or cooling towers. Ponds are supplied by pipeline, and because there is no natural flow of water into and out of them, they tend to accumulate dissolved solids which reduce the efficiency of condensers. Therefore ponds must be periodically emptied and refilled with fresh water. Cooling towers use the principle of evaporation to remove heat. They also require less space (an advantage when land is at a premium) and use less water than other methods because water is recycled several times. As with cooling ponds, the water used in cooling towers accumulates dissolved solids with each cycle and must eventually be replaced.

Waste Disposal

The use of waterbodies to receive municipal and industrial wastes is based on the concept that watercourses can and do assimilate some contaminants through naturally-occurring instream processes. These contaminants may be diluted, making them less concentrated, may be broken down and absorbed by aquatic organisms, or may settle out on the bottom. The extent to which instream processes can absorb contaminants depends on the temperature and rate of flow of the receiving body, the nature of the contaminant, how much of it there is (compared to the volume of water), and how long the contaminant has been present in the water.

The technical term for the ability of a waterbody to transform or incorporate contaminants is *assimilative capacity*. In most Canadian provinces, assimilative capacity is viewed as a legitimate use of the water resource, at least for the conventional pollutants (BOD, dissolved and suspended solids, nutrients and micro-organisms). Assimilative capacity is no longer generally viewed as acceptable for toxic contaminants which are persistant or bioaccumulative.

Waste disposal is a consumptive use because certain aspects of the water environment may be used up, at least temporarily. Dissolved oxygen, for example, may be consumed during the decomposition of BOD from human sewage, leaving little or none left for fish. The discharge of contaminants may also limit the use of a waterbody for the same purpose downstream in much the same way that the consumption of quantities of water may deprive others of an adequate supply.



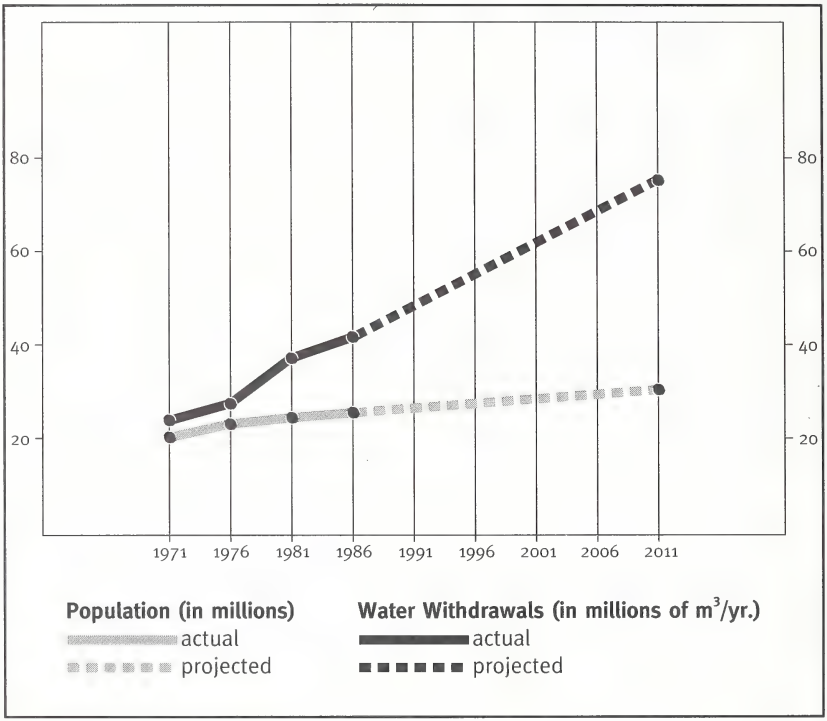
Adapted from *Summary Report, South Saskatchewan River Basin Planning Program*, Alberta Environmental Protection

Figure 12: *Instream Processes for Assimilation of Waste–Rivers can and do assimilate contaminants naturally by dilution, settling out and uptake by aquatic organisms. The assimilative capacity of a river depends on the rate and volume of streamflow and the concentration of contaminants entering the river.*

Trends in Water Use

In 1981, Canada withdrew nearly 38 billion cubic metres of water, mainly from lakes and rivers. Of this, nearly four billion cubic metres, or about 11 per cent, was consumed. Slightly more than three billion cubic metres were withdrawn for agricultural purposes, mostly for irrigation in southern Alberta and British Columbia. As a whole, agriculture uses accounted for three-fifths of our consumption nation-wide. The largest withdrawal, nearly 30 billion cubic metres, was for cooling and manufacturing. Thermalelectric plants in the Great Lakes region comprise about half of this amount. With these uses, consumption is much less (only about 20 per cent of withdrawals), because most of the water is recycled or

returned to the source. Municipal withdrawals were slightly more than ten per cent of the total; 80 per cent of this amount was returned to rivers and lakes as sewage effluent.



Sources: Water Withdrawals, 1971, 1976 and 1981, Environment Canada; 2011 projections, Tate in *Canadian Water Resources, 1987*; Population, *Human Activity and the Environment*, Statistics Canada, 1991

Figure 13: *Population Growth vs. Demand Growth for Water in Canada 1971-2001–The increasing gap between population growth and demand growth serves to illustrate that Canadians can no longer take their water resources for granted.*

The 38 billion cubic metres of water represents an increase of 13 billion cubic metres since 1972, a jump of slightly over 34 per cent in little more than a decade. This tells us that the increase in water use and consumption is not simply the result of population increases. We are using more and more water to support an increasingly higher standard of living. Our lifestyle now demands new water-using appliances, new chemical products and lush green lawns. We are consuming more electricity, aluminum, steel, gasoline, paper and plastics, all of which require water. We are producing agricultural commodities of marginal value on the international market. And we are producing more and more wastes, putting an even greater load on our water resources to assimilate them. Clearly, the supply of water, no matter how plentiful we perceive it to be, cannot keep pace with our voracious appetite.

In the future, we will need to re-evaluate both our water-using practices and whether reducing our consumption of water is compatible with our current lifestyle.

Studies which forecast future water-use scenarios indicate just how influential changes in water-using practices and technologies might be. Given current growth rates and no change in technology or water-using practices, withdrawals by the year 2011 should approach 74 billion cubic metres annually with consumption of about seven billion cubic metres each year, roughly a doubling from 1981. A scenario based on similar growth rates and levels of technology, but employing pricing mechanisms to encourage conservation, could reduce withdrawals to 47 billion cubic metres and consumption to roughly three billion cubic metres. Conversely, a high growth rate or altered production technologies aimed primarily at exploiting the full raw-material wealth of the country could push withdrawals as high as 90 billion cubic metres and consumption to nine billion cubic metres.

The impact of these increases will be felt most strongly in regions where reliable flows are exceeded by withdrawals. What these figures do not tell us is the impact of greater withdrawals and consumption on water quality. They do, however, indicate that, irrespective of the factors considered, our requirements for water will increase. Whether we can live within our means is a challenge for water managers, policy makers and the public at large.

Discussion Questions

1. How is the hydrological cycle related to problems of soil erosion and acid rain?

2. Water has been called the 'lifeblood' of the environment. What implication does this notion have for the survival of human beings?

3. Explain why contaminants in human sewage can dramatically alter water quality conditions even though they are identical to those found in natural waterbodies.

4. In the past, the destruction of aquatic habitat was viewed as a price to pay for human progress. Is this idea still valid today? Why or why not?

Recommended Readings

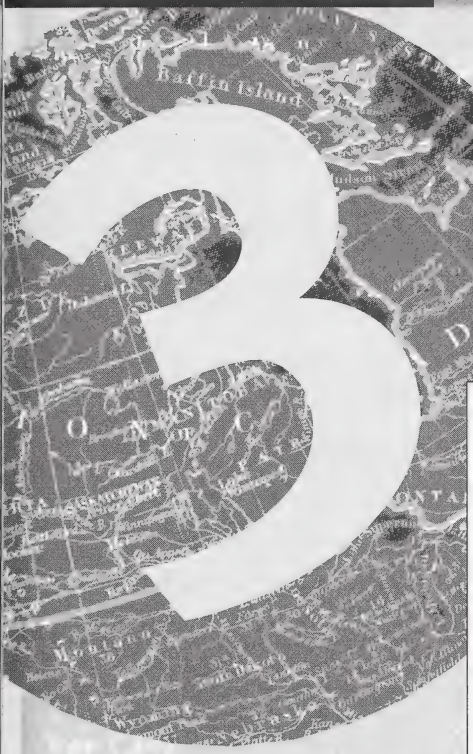
Rising to the Challenge
Peter H. Pearce, Canadian Wildlife Federation, 1988. *An excellent reference on fish and fishery policy for Canada, written by the Chairman of the Inquiry on Federal Water Policy*

Canadian Aquatic Resources
M.C. Healey & R.R. Wallace (eds.), Rawson Academy of Aquatic Science, Department of Fisheries and Oceans, 1987. *A collection of well-researched articles on water-related topics, including the role of water in wetlands, grasslands and forests.*

Company of Adventurers
Peter Newman, Viking, 1985. *The chronicle of the Hudson's Bay Company and its role in the discovery and settlement of Canada.*

Fresh Water Seas
Phil Weller, Between The Lines, 1990. *Traces the history of the Great Lakes and the impacts of uncontrolled industrial and agricultural development on the region. Includes a discussion of various government abatement programs, and suggestions for remedial measures for a Great Lakes clean-up.*

UNIT 3



Unit Focus

Because water flows across property lines and political boundaries, events which diminish its quantity and quality invariably affect others downstream. So we have evolved laws and regulations to limit conflicts between users and to ensure, whenever possible, that the supply of water does not limit our social and economic development. Traditionally, dams have been built to control the supply of water and sewage treatment plants constructed to remove the majority of pollutants in wastewater. In recent years, however, these methods have been challenged on the grounds that they are not sustainable. As well, citizens from all walks of life are demanding a greater say and a greater degree of government co-ordination in environmental decision-making.

Unit Objectives

At the conclusion of the unit, you should be able to:

1. distinguish between federal and provincial jurisdiction over water
2. define *riparian rights*
3. identify management strategies for allocating water
4. compare methods of *wastewater treatment*
5. define *assimilative capacity*
6. describe the goal of *multi-purpose management*
7. differentiate between water *quality guidelines* and *standards*
8. identify the role of *environmental assessment* in water resource planning.

Key Concepts

At the conclusion of the unit, you should understand that:

1. water is a mobile resource that ties all users along a water system together
2. institutional arrangements govern water allocation and pollution control
3. policies related to water management evolve in response to public attitudes and priorities
4. traditional water management strategies are aimed at making more water available and using the assimilative capacity of receiving streams to dilute wastes
5. there are costs and benefits associated with the management of water resources
6. water management decisions must frequently consider competing and conflicting interests and values
7. in principle, environmental assessment seeks to identify and weigh potential impacts of a project before approval and construction.

Hour Three Overview

Water is the lifeblood of the environment, endlessly cycling, endlessly delivering its nourishment to all of life. But water is also the steam in the engine of our economy, a commodity that, 'harnessed', produces electricity, makes deserts bloom, helps to keep our clothes 'whiter than white'. It's a key element in a Canadian life-style much of the world envies and wishes to emulate. But even though we live in a country which seems, on the surface, rich in water, competition for the benefits of this resource has often been intense. We've had to develop the legal and technological means to ensure, whenever possible, that the supply and quality of water does not limit economic and social development. In other words, we've had to 'manage' water.

In reality, it's not possible to manage water in any ultimate sense. The great panorama of the hydrologic cycle remains comfortably beyond our control (attempts at cloud seeding to create rain being no more than pinpricks in an elephant's backside). Rather, what we manage is our use and, to an extent, our abuse of the water delivered within our reach.

But who owns that water? Both water law and water management start from the answer to that question.

In Canada, water is a public resource 'owned' by the provinces on behalf of their citizens. But that ownership is limited by federal jurisdiction in a number of key areas and by water's own unceasing flow across the social and political artifacts known as boundaries. Water is mobile and, hence, shared.

As a result, water management itself is not static. It changes over time in both evolutionary and revolutionary ways and these changes mirror the ever-increasing complexities of our society. Since Confederation, growing demand for water and increasing pollution have prompted a re-examination of everything from resource ownership to environmental protection. Spurred by the emergence of environmental groups, the most revolutionary of these changes have occurred in the past three decades.

Travelling to the Saint John River Basin in New Brunswick, the essay **LAW** examines the constitutional basis for water management in Canada and, in particular, the institutional mechanisms for the allocation and protection of water. The delicate balance between the division of powers and the overlapping responsibilities of federal and provincial agencies has tended to compartmentalize rather than integrate the management of water. **IMPACTS** explores traditional practices of pollution control and the wisdom of using the environment as a dumping ground for wastes. Pollution, once considered little more than a local nuisance, has become endemic, but economic and political tradeoffs remain the *modus operandi* of pollution control. **DAM!** ferrets out the underlying questions of environmental

assessment with a tongue-in-cheek examination of the Rafferty-Alameda Dams controversy in southern Saskatchewan.

LAW—Essay Description

"It ran like an artery, the Saint John River, to the very heart of New Brunswick's soul—its history, its identity, its bounty of tall trees and red fields. It was, as natives called it, a gift of river. But then it clogged, and clotted, 'til finally somebody said:

'Where's The Law?'"

In latin, the word for river bank is *ripa*. While few pioneers on the Saint John River would have known that, they knew their rights in centuries-old English common law. If they owned land along a waterway, the water was theirs to use, or pollute, basically for as long as the neighbours downstream didn't complain.

These *riparian rights* were the beginning of water law in Canada but were difficult to enforce and hardly equitable. If water was to be the steam in the engine of economic development, it had to be 'owned' by the public and so the provinces have all claimed title to the water within their boundaries. This 'ownership' is limited however in several situations. Under the *Boundary Waters Treaty*, any waterway crossing or forming the Canada-U.S. border is a *transboundary waterway* and primary responsibility for its management falls to the two national governments. Canada's constitution, as well, establishes federal authority over a number of areas, including navigable waters and fisheries.

These overlapping jurisdictions often mean that water-related developments must be approved by both provincial and federal authorities. But there is yet another 'jurisdiction': *NGOs*—non-government organizations such as the Conservation Council of New Brunswick—have established themselves as 'watchdogs' and prods to the evolution of environmental law. In fact, the Conservation Council was instrumental in provoking the cleanup of the badly-polluted Saint John in the early 1970s.

Today, that cleanup is ranked as a major success. In essence the five legal jurisdictions involved agreed on a common goal—to make the river fishable and swimmable. This translated into a set of *water quality objectives* for the river which then provided a basis for determining allowable levels of pollution from communities and industries along the river.

But the long arm of the law goes much further than pollution control; in fact, to every nook and babbling brook in the province. Under recent legislation, activities such as forestry and farming are controlled for 75 metres on either side of a waterway, no matter how small. The idea is to create a 'living filter' of riparian vegetation that protects both water quality and fish and wildlife habitat.

But, even when a violation of these regulations is found, the focus is on education and co-operation rather than litigation. For, when all is said and done, law is an evolutionary process that reflects its times, its people and their concerns.

IMPACTS—Essay Description

"Human beings pollute just by existing, just by numbers and, particularly in North America, just by their lifestyle."

Say the word 'pollution', and the mind conjures images of belching smokestacks, unsightly landfills and foul-smelling rivers—images that are both disquieting and comforting: disquieting in their relentless pressure and grim message; comforting in their 'out-there' quality, a problem beyond our personal control and responsibility.

But consider this. Each urban Canadian produces nearly two kilograms of garbage and over 360 litres of household sewage every day. Multiply those figures by Canada's population, add the tonne of carbon dioxide the average car produces every year, then add the waste products from smelting, paper manufacturing, electrical production and the host of other industrial processes that afford most Canadians a lifestyle rated among the best in the world—and pollution is no longer 'out there'. We each contribute our share.

But what do we mean by the word pollution? Throw a cup of detergent into a wilderness lake and it disappears, seemingly without effect. Discharge millions of litres of phosphate-laden sewage every day and Lake Erie becomes eutrophic. Pollution is a relative term. Reflecting this, pollution is generally defined in law as the level of a substance that causes harm to human health or to natural systems, and pollution control is, theoretically, based on holding the introduction of pollutants below the level deemed to cause harm. In water management, a waterway is said to have an *assimilative capacity*, and the amounts of wastes permitted to be discharged are, in part, based on this capacity. But only in part.

In practise, economic, technological, and political factors are often as influential as assimilative capacity in the determination of permitted discharge levels. In the vernacular of water management, 'tradeoffs' are made to sustain economic activity. Ideally, these tradeoffs do not undercut environmental integrity. But that's not

always the case. Just for one example, although the *North American Acid Rain Accord* cuts acidic deposition levels in the United States and Canada to 1980 levels (a cut of almost 50 per cent from current levels), the acidification of forests and lakes in northern Ontario, Québec and the Maritimes will continue.

Philosophically, there is one major exception made in the use of assimilative capacity to control pollution: those toxics that are persistent in the environment and that bioaccumulate. Increasingly, for these materials there is no level deemed safe, and several jurisdictions have committed to their *zero discharge*. It's a goal that hasn't been achieved and may not be achieveable without a radical change in the tradeoffs game (a topic explored in the final hour of *The Living Flow*).

DAM!—Essay Description

> *"We are not environmentally insensitive. But we have to ask: whose environment is it, anyway?"*

It used to be that building a dam was a fairly simple proposition—and a popular one. Today, it's not quite that easy. Dams have become water management's quintessential battleground, pitting what seem to be diametrically opposed values—development, and conservation or preservation—against each other. The skirmishes between these forces take place in the arenas of legislatures and courts but there is no arena more important than the media, in particular television. It is here that public opinion can be courted, with ripple effects (for the winners) into the political process. Courting and manipulating the media, with the objective to present the 'facts', has become its own specialized war game.

These facts usually fall into two categories: *benefits* and *costs*. There are the benefits of economic activity, measured in jobs, production, and *social benefits* (protection from flood damage, hydroelectric power, an improved lifestyle and standard of living). Against that, there are the direct costs of construction and the costs of acquiring land where a dam will be built. Then there are *social costs*—farms, businesses and homes inundated, disrupted lives, and public facilities that have to be relocated. And there are also *environmental costs*, which are sometimes hard to estimate. For example, what's a duck worth? The answer depends on point of view more than any objective measure.

In theory, an *environmental impact assessment*, or *EIA*, looks at the total balance of these benefits and costs to determine if a project should go ahead. But few governments have been willing to allow their power of largesse to be limited by an EIA panel. In practise, EIAs concentrate on mitigative measures that eliminate or reduce the environmental consequences of a project but still allow it to go ahead.

Complicating the picture still further are the inevitable jurisdictional tussles between the federal government and the provinces. While provinces use EIAs, their use is often discretionary. Until 1992, the federal government also had an environmental assessment review process, known as the *Environmental Assessment and Review Process* (*EARP*), that was sometimes applied to projects under exclusive federal jurisdiction. But the federal government hesitated to apply the EARP to provincial projects... until a federal court ordered it to follow its own rules and conduct an *Initial Environmental Assessment* of the Rafferty-Alameda Dams project in southern Saskatchewan. For *The Living Flow*, it was the perfect opportunity to show the environmental assessment process in action... until the war game started.

Study Five: Water and the Law

The escalating demand for water in Canada has increased the competition and heightened the potential for conflict among users, particularly where supplies have become scarce or degraded in quality. The most intense competition for water occurs among users sharing a common watercourse. Here, the withdrawal or pollution of water by one party invariably limits the use of water by others because each use requires a certain amount of water at a particular time and of a particular quality. Fish, for example, need more water in the spring when they are spawning. Industries that use water for food processing and fertilizer production need an assured, year-round supply which is low in dissolved solids. Water-based recreational activities such as swimming require warm weather and water that is free from pathogens.

Given the enormous social and economic importance of water, governments at both the federal and provincial level have tried to ensure, whenever possible, that water resources are equitably shared and that the impacts of pollution and development are minimized. While the mechanisms for managing water vary from place to place, most jurisdictions have opted for a set of rules which govern the allocation of water and the protection of water and environmental quality. Some of these rules are contained in *policy*, but most are written down in *laws* and *regulations*. In today's society, where water management has become the complex and often delicate art of balancing the rights of individuals with the rights of society and human needs with those of other organisms, laws afford governments the power to prevent the worst excesses of abuse and the ultimate mechanism for resolving disputes.

Exercising authority over water becomes difficult in cases where lakes and rivers cross provincial, state or national boundaries. Laws, like other institutional mechanisms, reflect the values, beliefs and priorities of the society that makes them, and what's important in one particular jurisdiction may be less important in

a neighboring one. And self-interest often plays a part where one jurisdiction cares little for the impacts of its own activities on a downstream (or downwind for that matter) jurisdiction. In these cases, disputes over water must be resolved by negotiation or settled in the courts.

Laws must also be flexible and responsive to change. In recent years, for example, we have learned a great deal more about the effects of toxic contaminants on human health, and this knowledge has prompted revision of water quality regulations. As well, a heightened sense of environmental awareness and the need to protect aquatic habitats has influenced the way governments at both the federal and provincial level are assessing the potential impacts of water resource development projects.

The Constitutional Framework

Regulation of the water resource in Canada has evolved out of a recognition that it is part of the public domain and therefore needs to be managed for the common good. Because Canada is a federal state, the power to enact laws is constitutionally divided between the federal parliament and provincial legislatures. Under the *British North America Act* (now the *Constitution Act*), provinces have jurisdiction over water within their own boundaries except for federal lands, such as national parks and Indian reserves, and the power to issue licenses and legislate on matters such as municipal and industrial water supply, power development, recreation, and pollution abatement. Provinces may delegate some of these powers to regional and local governments.

The Constitution provides for exclusive federal jurisdiction over navigation and shipping, as well as authority for fisheries and the management of water in the Territories and on Indian lands. The federal government also has the power to negotiate treaties with foreign governments. One of the more controversial aspects of federal authority is the provision for the "peace, order and good government" of Canada. This is considered a *residual* power because it can be applied to any matters not specified elsewhere in the Constitution. In the past, this power was thought to justify federal intervention in natural emergencies, such as war or famine. More recently, the provision has been interpreted to mean matters of national concern such as the pollution of an interprovincial river.

In certain instances, federal and provincial jurisdictions are unclear. The *Fisheries Act* does not take priority over conflicting provincial legislation, and in many parts of Canada, to avert jurisdictional conflict, the federal government has delegated enforcement of this legislation to provincial authorities. Nevertheless, the Fisheries Act is one of the most effective pieces of federal legislation for dealing with water pollution as it relates to fish.

There are several instances where federal legislation is specifically aimed at promoting recognition and joint initiatives with the provinces. The most important of these is the *Canada Water Act*, which has fostered federal-provincial water management planning studies in the Okanagan, Saint John, Qu'Appelle and Saskatchewan-Nelson Basins. The *Prairie Farm Rehabilitation Act*, enacted in 1935 to alleviate severe problems of drought and soil erosion, is now administered in consultation with the three prairie provinces and over the years its agency, the Prairie Farm Rehabilitation Administration (PFRA), has developed water supplies for farms, communities and irrigation projects. Recent joint ventures along the St. Lawrence River and in Halifax Harbour illustrate the degree to which federal and provincial governments can work together.

The federal government also plays a role in the management of interprovincial rivers. In 1969, the three prairie provinces and the Government of Canada signed the *Master Agreement on Apportionment*, which established a formula for sharing the waters of the Saskatchewan-Nelson system. Under the agreement, Alberta (where these rivers have their headwaters) may consume, divert or store 50 per cent of the natural flow of water arising within its boundaries before it passes into Saskatchewan. Saskatchewan, in turn, may consume, divert or store 50 per cent of the remainder and 50 per cent of the flow originating within its boundaries but must pass 50 per cent on to Manitoba. Although the present agreement applies only to water quantity, the Prairie Provinces Water Board, a joint provincial-federal agency responsible for administering the agreement, is in the process of establishing water quality standards at the Alberta-Saskatchewan and Saskatchewan-Manitoba borders. Such standards would have important implications for water quality management in Alberta and Saskatchewan.

International Agreements

Over 3,800 kilometres of lakes and rivers form the border between Canada and the United States, from the St. Croix and St. John Rivers in New Brunswick to Lake of the Woods in western Ontario. Contention over these and other waterways along the 8,900 kilometre boundary has been part of bilateral relations dating back to the last century.

Within Canadian federal and provincial jurisdictions, the use of water and protection of water quality can be assured, though imperfectly, through legal and institutional means. But where water forms a boundary or flows across a national border, no overriding authority oversees the rights and obligations of the people using the water. Arrangements must therefore be worked out between the two sovereign governments acting to protect their interests as they perceive them.

In response to a growing number of water problems, Canada and the United States signed the *Boundary Waters Treaty* in 1909. This treaty set forth principles to guide boundary water use and management. It also established the *International Joint*

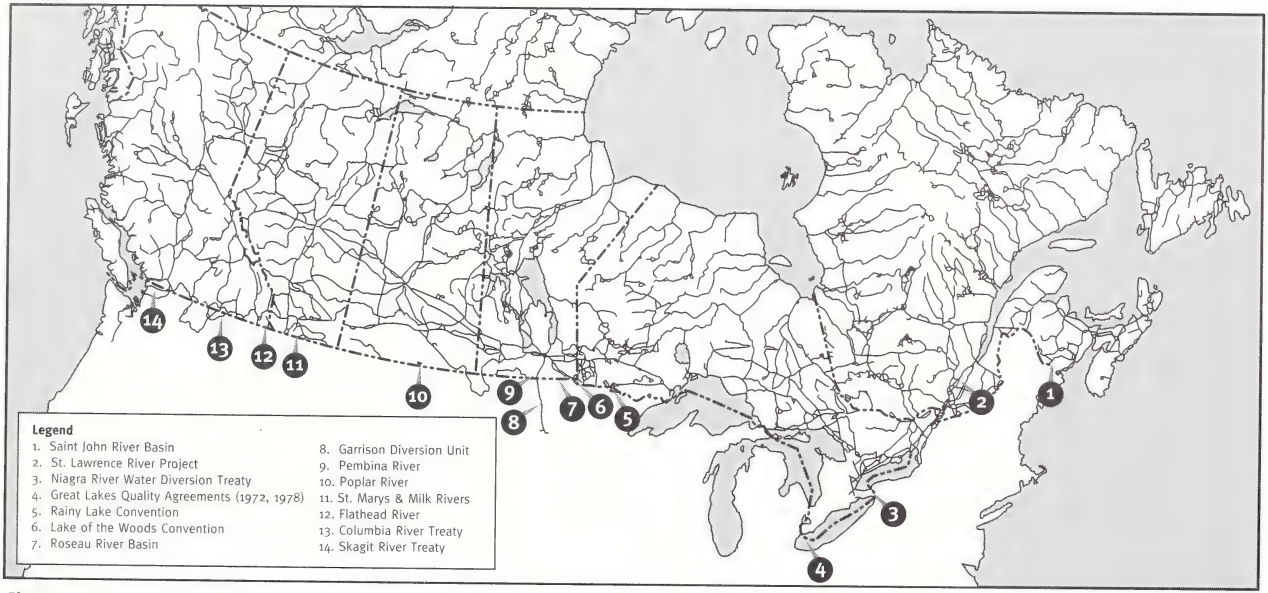

Legend
1. Saint John River Basin
2. St. Lawrence River Project
3. Niagra River Water Diversion Treaty
4. Great Lakes Quality Agreements (1972, 1978)
5. Rainy Lake Convention
6. Lake of the Woods Convention
7. Roseau River Basin
8. Garrison Diversion Unit
9. Pembina River
10. Poplar River
11. St. Marys & Milk Rivers
12. Flathead River
13. Columbia River Treaty
14. Skagit River Treaty

Figure 14: *International Agreements, Treaties and Studies by the International Joint Commission–Signed in 1909 between the United States and Canada and Great Britain (on behalf of Canada), the Boundary Waters Treaty has provided the framework for the peaceful sharing of transboundary waterways. The Treaty provides equal rights for both parties and contains a clause that, ostensibly, prohibits pollution.*

Commission (IJC), a six-member body (three members from each government) with responsibility to approve water projects which might alter the quantity and/or quality of transboundary waters, and to arbitrate disputes. The IJC is, in effect, a quasi-judicial body, operating independent of government direction. The Treaty itself contains several provisions of historic and current significance. First, it entitles American and Canadian commercial shipping to "free and open" navigation of boundary waters. Second, it establishes the principle of equity in that both countries have equal and similar rights in the use of boundary waters. Third, it contains an anti-pollution clause which states that boundary waters "shall not be polluted on either side to the injury of health or property on the other". Finally, it sets priorities for water uses (in order: domestic and sanitary, navigation, irrigation and power production) to resolve conflicting demands on the shared waters.

In the past two decades, the IJC has increasingly focussed its attention on environmental problems. Its work on pollution in the Great Lakes became the basis of the *Great Lakes Water Quality Agreements* of 1972 and 1978 and the 1987 *Protocol Amending the 1978 Agreement*. In the mid-1970s, the IJC was called upon to adjudicate a dispute between the U.S. and Canada over the Garrison Diversion Unit (GDU). Several years before, the United States had begun diverting water from the Missouri River to irrigate land in North Dakota. Central to Canada's case against the project was the fact that fish eggs and parasites from the Missouri system would enter Lake Winnipeg (via irrigation return flows into the Red and Souris Rivers) and destroy the lake's freshwater fishery. For this and other reasons, the GDU was halted mid-way through its development. More recently, the Commission has investigated the cross-boundary implications of the Poplar Power Project in Saskatchewan and coal development in the upper Flathead Basin of British Columbia.

The Boundary Waters Treaty has served a valuable function in protecting water interests of Canadians, and its principle of equity is particularly important in view of the relative size and power of the two countries. Were it not for this treaty, our co-operation with the Americans would have been more limited and relations more strained.

Water Allocation

The allocation of water in Canada has its origins in common-law practices of the Romans and later the English. Certain aspects of the law gave property owners whose land was adjacent to a waterbody the right to unlimited use of the water for domestic purposes, which at the time included agriculture. The property owner could also use water for other 'benefical' purposes, as long as the use was reasonable and did not appreciably decrease the quantity and quality of water available to others who depended on the same source of supply. This concept was known as the doctrine of *riparian rights* (*ripa* is Latin for bank; hence, 'rights of the riverbank').

With economic growth and industrialization, governments at the provincial and federal level in Canada recognized the difficulties posed by riparian rights and enacted laws that transferred ownership of water resources to the Crown and established mechanisms for the allocation of water rights. (Technically speaking, the Crown did not own the water outright, but was empowered to regulate the use of water by granting water rights.)

Today, the withdrawal, use or storage of water requires permits or *licenses* (the exception is the withdrawal of water for domestic purposes). Licenses are granted for irrigation, hydroelectric power generation, and municipal and industrial use, but rarely for recreation and fish and wildlife. Licenses are also given out on a first-come, first-served basis (the principle of *prior allocation*), although the licensing system may set out priorities of use when water is scarce. In these cases, water for one use can be reallocated to another of higher priority, irrespective of prior allocation, as long as the user deprived of water is compensated. This provision has rarely been used, but is likely to become important as the demand for water grows.

Anyone wanting to obtain a license must submit an application to the appropriate government department describing the purpose for which water will be used, an estimate of the quantities that will be used, and detailed plans for proposed works to withdraw, divert or store water. The application is then reviewed to ensure that granting the license will not detrimentally affect the water supply, existing licensed users, users with other rights (e.g. riparian), or the lands and facilities of the surrounding area. Licenses may contain provisions limiting withdrawals during certain periods or requiring minimum flows past the point of withdrawal.

This system of allocating water is likely justifiable but not necessarily equitable. Those planning to spend considerable capital in water-related development (industries, utilities or irrigators) understandably want to protect their investment by having guaranteed access to the supply. On the other hand, water rights are generally granted in perpetuity (they are seldom subject to review or alteration) and allow the licensee to use all of the water stipulated in the license, regardless of the needs of other users. Although some provincial statutes include provisions for water conservation, they are often poorly defined, and water-using practices are rarely scrutinized. As water becomes a more important issue, the licensing system itself may have to be more closely examined.

Water Quality Protection

The laws and regulations governing water quality are designed to limit the entrance of contaminants into waterbodies and to ensure adequate water quality protection for the most sensitive of water uses. But the term 'quality' is somewhat relative, because what is an acceptable quality for one use may not be for another. Compounding this definitional difficulty is the fact that, in nature, there is no such

thing as 'pure' water, and the quality of natural water is highly variable, not just from location to location but also from season to season, even day to day in some cases.

Wastewater Treatment

The treatment of municipal and industrial wastes is generally accepted as the most effective way to limit the entrance of contaminants into waterbodies. First, the technology of wastewater treatment is well understood and sophisticated, and virtually all contaminants can be removed (the major constraint is usually cost). Second, wastes from municipalities and industries are discharged into receiving streams by means of pipes or conduits, so that the composition of the effluent can be determined and measured. Finally, the discharge of wastes into lakes and rivers is regulated, and license violations are subject to penalties under existing statutes.

Wastewater treatment generally falls into three catagories: *primary, secondary* and *tertiary.*

Primary treatment, a physical or mechanical process, screens out large objects like sticks and rags and removes suspended solids by sedimentation. This level of treatment effectively removes 25 to 30 per cent of biochemical oxygen demand (BOD) from wastewaters.

Secondary treatment is a biological process using bacteria to decompose organic substances in wastewaters. Oxygen may be added to accelerate this decomposition (*aerobic conditions*), although decomposition also occurs in the absence of oxygen (*anaerobic conditions*). During this level of treatment, 85 to 90 per cent of BOD and suspended solids are removed, along with some nutrients and pathogens. Some communities chlorinate their effluent to remove potentially harmful bacteria, but this process may create carcinogenic trihalomethanes. A few communities use ultraviolet light disinfection to avoid this controversy.

Tertiary treatment is mainly a chemical process that removes additional contaminants such as nutrients and inorganic dissolved solids. This level of treatment has most often been used to reduce phosphorus loadings in municipal wastewaters.

Despite the general acceptance of municipal wastewater treatment, not all communities across Canada have implemented the practice. A 1984 national inventory revealed that only 2,164 of Canada's 3,250 communities had sewers, and of these, only 1,442 had some kind of sewage treatment. In total, only 12 million Canadians are served by sewage treatment plants. The cities of Saint John, Halifax and Victoria have no wastewater treatment at all, and Vancouver has only primary treatment. Until recently, Montreal was dumping raw sewage into the St. Lawrence River. In 1987, the city invested $5 billion to construct a primary treatment facility.

Against such costs, cheap disposal in nearby waterways remains an attractive, but controversial, option for many communities.

Industrial wastes pose a more serious problem to water quality than municipal wastes because they are generally more difficult to treat. Of the 65 identified types of industrial wastes, 39 can be treated by processes just described. The remaining 26 include such contaminants as phenols, chlorinated hydrocarbons, heavy metals, sulfides, chlorides, and oils and grease. Various new technologies that use incineration, biological and chemical oxidation, and precipitation have been proven effective in the removal or recovery of many of these contaminants. Their cost, however, is high.

Water Quality Objectives and Standards

Water quality is assessed in terms of measurable physical, biological and chemical *parameters* (e.g. dissolved oxygen, temperature, bacteria). These parameters, singly or together, give a picture of what's in water and at what concentrations. They do not tell us, however, whether water quality is acceptable for a particular use. In fact, there is no absolute measurement of what constitutes 'good' water quality, because each use has certain water quality requirements. For example, bacteriological contamination of water renders it unsafe for human drinking but not for cattle or waterfowl, and while copper in minute quantities is essential for proper growth and metabolism, it's poisonous to aquatic plants in higher concentrations. To deal with this question, governments at both the provincial and federal levels have established *water quality objectives* for a wide range of parameters and uses. To illustrate, for drinking water, Ontario's objective for total and fecal coliform bacteria is less than ten organisms per 100 mL. For direct contact recreation (swimming), the numbers of total and fecal coliforms should not exceed 1,000/100 mL of water. These objectives are also expressed at *maximum allowable concentrations*; for example, the M.A.C. for arsenic in drinking water is .05 mg/L.

At the federal level, water quality objectives have only been developed for drinking water quality. However, several provinces, including Alberta and Ontario, have established water quality objectives for surface waters. Surface water objectives have also been set internationally for transboundary rivers.

The difficulty with these objectives is that *ambient water quality* is influenced by natural as well as human factors. In practice, it is often difficult to monitor and measure ambient water quality along the entire waterbody or control the entrance of contaminants from non-point sources. Surface water quality objectives, therefore, are viewed as guidelines rather than legal requirements.

Most regulatory systems, on the other hand, are aimed at measuring and controlling the quantity and quality of wastes that are discharged directly into the

water environment. Waste discharge, like water allocation, is controlled by a permit or license that specifies maximum allowable levels of contaminants in effluents. These are usually referred to as *standards* and are enforceable (although they are not always enforced). Most jurisdictions factor in the assimilative capacity of the receiving waterway in the establishment of these standards. But it is difficult if not impossible to determine the precise way a receiving stream will assimilate contaminants, so assimilative capacity is generally calculated according to *dilution ratios*, that is, the extent to which the receiving body will dilute and therefore lower the concentrations of contaminants in the effluent.

As a general rule, regulatory agencies set the terms and conditions of licenses to meet pre-established water quality objectives. This is done by considering the treatment technology and the assimilative capacity that will, in combination, result in desired ambient water quality in the receiving body. Additional considerations include the needs of downstream users and the relative hazard of the polluting substance (industries, for instance, may be prohibited from discharging a particularly noxious substance if it can be shown to have an impact on drinking water quality or cause harm to organisms). An important exception is made with respect to the so-called *mixing zone*—the area of a receiving body immediately downstream from the discharge point. Although the length of the mixing zone is not precisely defined, it is thought to extend to a point downstream where concentrations of contaminants are uniform. By and large, water quality objectives do not apply to the mixing zone, although most jurisdictions do not permit conditions within the mixing zone to be lethal to humans or aquatic organisms.

Part of the reason for this regulatory approach is the fact that it is much simpler to control discharges than ambient water quality, which is affected by non-point source pollutants and variations in flow. As well, the use of assimilative capacity as an underlying principle of water quality management is based on the technological and economic difficulty of achieving 100 per cent removal of contaminants from wastewater. The course of action that governments have taken is to reduce pollution while taking into consideration the costs of pollution abatement, the success of pollution abatement measures, and the seriousness of the impacts of contaminants on overall water quality. Traded off in this approach is the natural condition of the receiving waterway. The presence of contaminants in waterbodies does restrict their use and often has detrimental effects on aquatic life.

Some have argued that we should have ambient water quality standards, based on legislation, rather than voluntary objectives. Governments have been reluctant to legislate such standards because they would be difficult to enforce (to prove, for example, that industry A was the culprit, rather than municipality B, or even a naturally-occurring source). One federal piece of legislation, the Fisheries Act, does contain water quality regulations protecting fish. This legislation has been influential in establishing national baseline standards for certain industries, including pulp and paper, petrochemical refining, chlor-alkali and metal mining.

There has also been serious discussion about establishing instream water quality standards on certain transboundary rivers.

The enforcement of water quality standards and regulations is as much a political as a legal process. Prosecution is often influenced by a polluter's ability to pay for advanced technology, the political and economic influence of the polluter, and the degree of public opposition to the polluting practice. Regulatory agencies in Canada have usually chosen to be flexible in their approach to industry, and licensing standards are often negotiated, particularly with respect to what technology should be used. Agencies may also grant *variance certificates* allowing industries to exceed terms and conditions of the license under certain circumstances, or issue *control orders* stipulating that treatment or process technology be upgraded according to mutually agreed-upon timetables. In rare instances, a regulatory agency may shut down a facility through a *stop order* if contaminants in the effluent are judged to be of immediate danger to human life and property.

Many lawyers and regulatory agencies in Canada have argued that negotiation is preferable to litigation as a means of implementing water quality standards because prosecution may result in protracted legal battles after charges have been laid. There has also been a tendency by the judicial system to levy fines that have little practical value in deterring further license violations. One review of the federal *Fisheries Act* showed that of the 144 pollution charges laid between 1985 and 1988, only 66 resulted in convictions. In these cases, the average fine for each conviction was slightly over $4,000.

Water Resource Planning and Environmental Assessment

Water resource planning seeks to direct the management of water toward certain objectives. At one time, the sole objective of planning was to encourage economic development, and water projects were usually *single purpose* (e.g. the generation of hydroelectric power). During the 1960s, however, growing public concern over the impact of large-scale projects on the environment led to the incorporation of *environmental assessment* into the planning process. The main purpose of environmental assessment is to predict the environmental impacts of a proposed project while it is still in the planning stages and to require that steps be taken to *mitigate*, or reduce, these impacts. Today, an environmental impact assessment (EIA) or environmental impact statement (EIS) is common practice in most resource development initiatives.

The other major change in planning is the involvement of the public through open houses, task forces, advisory groups and public hearings. Public participation is a relatively new phenomenon in Canada, brought about in part by a growing frustration among individuals who felt unable to influence decisions affecting them personally. In some cases, management decisions resulted in environmental, social

and economic losses which might have been alleviated had public preferences been more adequately addressed. The public today is better educated about and more aware of environmental issues, and has come to expect a more active role in the decision-making process. Environmental assessment increases public access to decision-making by requiring that the assessment be considered at a public hearing before an administrative board.

Ideally, EIAs begin with a comprehensive inventory of environmental resources. Potential impacts of a project's construction and operation are then identified, along with mitigative measures. This sequence is important, because if no inventory is compiled before a project commences, there will be no way to evaluate the project's impacts. The costs of impacts and mitigative measures can then be evaluated against the project's benefits to determine whether the project is viable. Typically, benefits and costs are expressed in monetary terms, such as the increased value of agricultural production or hydroelectric power generation and the cost of construction. It is much more difficult to derive economic values for wildlife or recreation, especially when well-established markets for these activities are not deemed to exist. Consequently, these uses are often omitted from benefit/cost analysis even though their value, in social and environmental terms, may be considerable.

In principle, environmental assessment provides a legal mechanism for stopping a project before it is built. However, federal and provincial governments have been reluctant to make the use of this tool both mandatory and binding, preferring to retain the discretionary power to use or not use environmental assessment, and to accept or not accept the recommendations made. For example, in 1973, the federal government introduced the *Environmental Assessment and Review Process* (EARP) to assess projects which it undertook or funded or which were located on federal land. But EARP was established by an Order-in-Council—it was a policy of the federal government, not a law—and its implementation was left to individual federal departments rather than to a regulatory body. Its greatest weakness was that each department could decide whether or not an assessment was required for any projects under its authority and these decisions were often made for political rather than environmental reasons. In particular, the federal government has been loath to apply the EARP to water development projects undertaken by the provinces. (Similar criticisms can be made of provinces where cabinets or environment ministers are given discretionary powers over which projects should be subject to an environmental assessment.)

In recent years, there have been a number of precedent-setting legal battles over the application of the EARP process (and, by extension, federal jurisdiction) to provincial projects that have transboundary and interjurisdictional impacts. Three of these, the Rafferty-Alameda Dams project, the Oldman Dam project and the Alberta-Pacific pulp mill, were in western provinces. The fourth was the James Bay Hydroelectric Project Phase II, in the province of Québec.

Constitutionally, the federal government had the authority to act in all of these cases as it has jurisdiction over fisheries, native issues and interprovincial and international relations. While the federal courts have not only supported this position but required federal assessments of these projects, the provinces have seen EARP as an infringment of their powers, and more often than not the federal government has been pushed into assessing the impacts of projects which are nearly completed. This situation has created duplication and inefficiency, and undermined the credibility of the environmental assessment process at both levels of government.

In early 1992, the federal government passed the *Canadian Environmental Assessment Act*, replacing the EARP guidelines with legally enforceable regulations. The Act defines the federal role in environmental assessment: where it is required to approve a permit or license, where it funds projects or when it builds on or disposes of federal land. It also calls upon the provinces to jointly review projects where federal jurisdiction is involved and to provide for open, public hearings. This move puts into law both the assessment of environmental impacts and the co-ordination of these assessments with the provinces.

The Athabasca Pulp Mills: A Case Study

Ask anyone in Canada where Alberta is and they'll most likely say that it's part of the prairies. What Canadians—and many Albertans—do not realize is that almost two-thirds of the province is covered by forest—318,000 square kilometres in all—an area equivalent to the size of Great Britain. The vast majority of Alberta's forests are classified as boreal, *meaning northern. The term actually refers to a huge ecosystem stretching across the high latitudes of Europe, Asia and North America. This ecosystem makes a vital contribution to global air quality and water balance.*

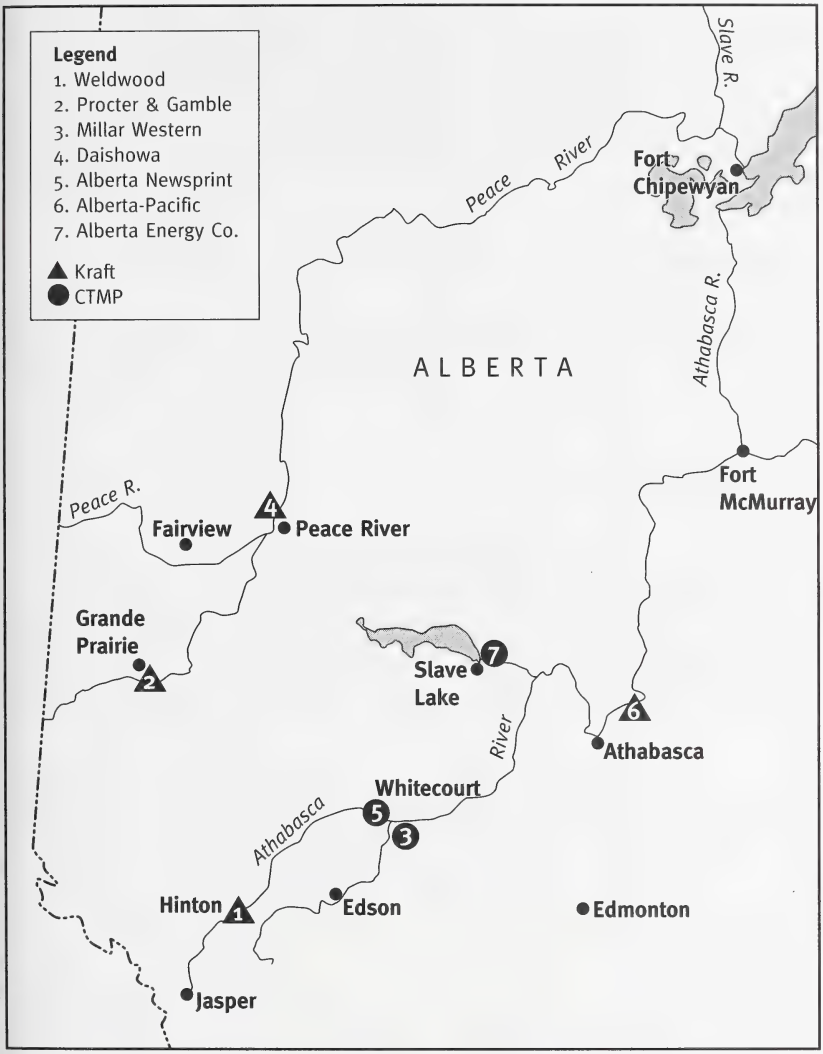


Figure 15: *Pulp Mills in Alberta–Since 1987, over $3 billion in public and private funds has been invested in new pulp mills. Most of the pulp produced in northern Alberta will be exported to the United States, Mexico and Japan.*

In Alberta, the boreal forest consists of white and black spruce, trembling aspen and balsam poplar, with occasional stands of lodgepole pine, tamarack and balsam fir. One of the largest natural areas in the province, the forest is home to elk, deer, moose, martin, fisher, lynx, wolf and bear. The diversity and productivity of its vast wetlands provides staging and nesting habitat for numerous species of waterfowl, including the most northern population of American white pelicans. In the old-growth stands, one finds raptors, woodpeckers and other species of birds that nest in the hollows and cavities of mature trees. And because the forest is remote, it is the last refuge of the whooping crane, bald eagle, peregrine falcon, woodland caribou, American bison, wolverine and other threatened species.

The boreal forest is also a major timber resource. White spruce and lodgepole pine are prized for their lumber in regions where they are of sufficient size to be logged. But the mixed-wood stands of aspen and black spruce have been largely ignored because they were thought to have little commercial value. That is, until recently.

In 1987, the Alberta government took a giant step toward economic diversification by announcing it was opening its northern forests to development. In addition to sawmills, lumber mills, strandboard plants and a newsprint facility, the province planned to construct five new pulp and paper mills and expand two others, generating in the process an estimated 12,000 new jobs. For a government saddled with an $8 billion debt, the $3.5 billion in capital investments and $1.5 billion in pulp taxes and royalties over the next twenty years were too good to pass up. Thanks to global shifts in the economy and a booming pulp market, a forest Alberta had once regarded as a 'patch of weeds' had become a resource of great value.

Like water, forests are provincially-owned Crown resources, and the province has the legislative right to grant leases to forest industries. These leases, called forest management agreements *or* FMAs, *cover the cutting and replanting of trees and the payment of royalties over a twenty-year period. Most provinces set their FMA royalties annually. Alberta, however, has pegged its royalties to changes in the price of pulp, a strategy which will benefit the industries. Within a sixteen-month period, and without conducting public hearings on these FMAs, the government leased 221,000 square kilometres, or nearly 60 per cent of the boreal forest, to a dozen firms. Two of these, both Japanese companies, were granted rights to tracts covering a total of 114,000 square kilometres, roughly 15 per cent of the entire province. To further insure the success of diversification, the government granted the mills assistance and loan guarantees in excess of $1 billion. Alberta Pacific (ALPAC), controlled by Mitsubishi Corporation of Japan, was given a $300 million loan (the province also invested $350 million in the mill). Daishowa, another Japanese corporation, received $65 million of public funds for roads, a rail spur and a bridge near Peace River. Alberta Energy obtained $96 million in loan guarantees; Weldwood of Canada ($235 million) and Alberta Newsprint ($200 million) were other recipients.*

The major environmental concern over the pulp mills is not just for the consequences of clear-cutting immense tracts of lands, but also for the impacts the mills will have on the Peace and Athabasca Rivers. Pulp mills are notorious polluters, although their production technology was been vastly improved over the past dozen years. The pulp mills in Alberta are of two types: Weldwood Canada in Hinton and Proctor and Gamble near Grande Prairie both operate bleached kraft *pulp mills; Miller Western has a* chemi-thermo-mechanical pulp (CTMP) *mill in Whitecourt. What distinguishes a kraft from a CMTP mill is the way wood fibers are separated from the lignin 'glue' that holds them together. In kraft mills, the separation is more complete and the fibres remain more intact. Kraft pulp, therefore, is superior to CMTP pulp and more amenable to bleaching. Bleaching increases the whiteness of the paper product, and it is this characteristic that has created an international demand for bleached kraft pulp. On the negative side, bleaching also produces* organochlorines, *including dioxins and furans, which are known to be toxic to aquatic life and humans even in minute concentrations. Pulp mills of both types also produce large amounts of organic wastes or BOD (biochemical oxygen demand). If decomposition of these organic loadings lowers oxygen levels beyond a certain level, fish and other aquatic organisms will suffocate.*

Alberta's mechanism for controlling water pollution is the Clean Water Act, *which requires all waste discharges to be licensed. The license sets the terms and conditions under which contaminants can be discharged (such as allowable concentrations of contaminants in effluents) and the volume and timing of effluent release. Licenses also define specific monitoring and operating requirements and the type and design of the treatment facility, including the kind of wastewater technology installed.*

Wastewater technology is not well understood by the general public, but it is by government officials who grant licenses and by wastewater engineers employed by pulp and paper companies. The two groups usually negotiate whether the wastewater treatment system will employ best practical technology (BPT) *or* best available technology (BAT). *BPT is that treatment method in general use and financially feasible to implement. BAT is that treatment method most likely to work in controlling pollution. (Comparisons between different treatment methods are often made through reference to the quantity of contaminants released per unit of production, e.g. kilograms per air dried tonne of pulp. The lower the quantity per production unit the better the system and the more likely that it will be designated as BAT.) The decision to use one or the other depends on the perceived degree of hazard and the toxicity of the contaminants in question. Because the kind of treatment technology is incorporated into a license (and becomes, in essence, a legal requirement) it therefore carries with it financial ramifications for the licensee.*

When the pulp mills were announced, Ian Reid, then Minister of Alberta Environment, stated that the province would require its pulp and paper industry to

implement environmental standards reflective of 'leading-edge technology' (i.e. BAT). The government's intention at the time was to make the new Alberta mills world leaders in controlling the production of dioxins and other organic compounds and in minimizing their release into the environment. To its credit, Alberta has followed through on its commitment, and kraft pulp mills like Daishowa and ALPAC have been required to incorporate technologies reducing the amounts of chlorine during the bleaching stage. As a consequence the ALPAC mill was projected to release just 1.5 kilograms of organochlorines per air-dried tonne of pulp, a level that will not generally be required of Canadian kraft mills until the mid-1990s.

Despite these commitments, the government did not know what the cumulative impact of trace amounts of dioxins and furans from five new mills would have on the biota of the Peace and Athabasca Rivers or on the system of interconnected waterways flowing through the Northwest Territories to the Beaufort Sea. It is known, however, that these chemicals are both persistent and bioaccumulative.

This point was noted by the EIA Review Board, a joint provincial-federal panel established in the wake of the Rafferty-Alameda court decision requiring federal assessment of projects affecting federal jurisdiction. During public hearings on the proposed ALPAC mill, Environment Canada took the position too little was known about the long-term cumulative effects of pulp mill development. In its report, the Board agreed. While acknowledging that the mill would be one of the least polluting bleached kraft pulp mills in the world, the Board recommended the mill not be built until further studies could be conducted on the Athabasca River. These studies were necessary, it said, to insure that there would be no serious impacts to life in the Athabasca River and for downstream users. Of particular concern to the Board was the fact that fish might contain levels of dioxins that would jeopardize the health of aboriginal people, whose weekly consumption of fish exceeds that of most other Canadians by a factor of ten. The Board also noted that the projected pulp discharges would cause levels of dissolved oxygen too low in winter to support fish, a fact demonstrated in modelling exercises by Alberta Environment staff.

Soon after the Review Board announced its decision, it was replaced by a second panel appointed by the provincial government, and this panel approved the mill based on a revised process submitted by ALPAC reducing the rate of discharge of organochlorines to just one kilogram per air-dried tonne of pulp (one of the very best in the world). The move surprised and angered many Albertans because the government had insisted all along that it wanted a fair and impartial review of the mill. Not surprisingly, Ralph Klein, then Minister of the Environment, defended his government's decision, insisting that the ALPAC mill was an example of sustainable development because it would protect the Athabasca for future generations. But the government's priorities were clearly on the development side. Neither the minister's department nor experts on either panel knew what levels of toxic substances could be considered safe. Essentially, the mill was approved

because it was going to use the best technology available, and the alternative—delaying development while considerable time and money was invested in answering the environmental questions—might have closed the 'window of opportunity' in the bleached kraft market.

The site of the ALPAC mill is on the south side of the Athabasca River near Prosperity, Alberta. The mill is the crown jewel in the Alberta government's plan, and, at a cost of $1.6 billion, will be the largest bleached kraft pulp production facility in the world. The controversy surrounding the mill's approval has split the Town of Athabasca into two camps: those who want the 1,000 or so jobs the mill will provide, and those who fear that this mill, along with the others, will cause air and water pollution, deforestation, soil erosion, and habitat and wildlife destruction. Mitsubishi will pay royalties of $1.40 for 16 cubic metres of aspen. That same aspen, converted to bleached kraft pulp, is worth $950. And the paper refined from that pulp is worth between $1,300 and $2,000. Alberta will see very little of this wealth because 90 per cent of ALPAC's pulp is being exported to the United States, Japan and Mexico. If pulp prices remain high, Mitsubishi will likely recoup its investment in three to five years. Albertans, on the other hand, could be sacrificing their vast northern forest and perhaps the quality of two great rivers flowing through it.

The Athabasca Pulp Mills case study exemplifies the current debate about large-scale development and the role of law in protecting environmental quality. It can be argued that Alberta Environment followed its own rules in approving licencing standards for the ALPAC mill. On the other hand, the question of whether the rivers will be able to withstand the cumulative impacts of new pulp mills remains unresolved. Even though the Department of Environment had not completed baseline studies on the Athabasca River, the government still opted for a 'technological' solution based on effluent discharges, and the continued use of assimilative capacity to dilute pollutants. This approach is questionable, especially when it is made without adequate knowledge of ambient water quality in the receiving stream.

While the Alberta government can be credited for subjecting the project to an environmental assessment, it compromised the intent of the EIA process by ignoring the recommendations of its review panel. Such a decision is perhaps understandable in light of the enormous foreign and provincial investment in development, and the pressure for regional employment to which the government was committed. But when jobs and wealth creation become the overriding goals of economic development, environmental concerns are often relegated to a position of secondary importance and the goal of sustainable development is compromised.

This point was made by aboriginal people living in the Northwest Territories, who argued that none of the existing, developing or proposed mills had taken their interests into account. They were not partners in development and yet, as people who lived on the land and used it, they were greatly affected by that development. It was their view that the project should be delayed until comprehensive water quality and fisheries data on the entire Athabasca watershed could be obtained. As well, they wanted to be part of these studies, reviewing them and participating in a management structure to oversee these waters in the future. At the present time, however, there is no legal mechanism governing the management of transboundary waters flowing from Alberta into the Northwest Territories. Without it, these aboriginal people will have little influence on decisions made in another jurisdiction.

Study Six: Water Shortages on the Prairies

The prairies of Canada cover a 500,000 square kilometre area of the provinces of Alberta, Saskatchewan and Manitoba. Ecologically, the prairies are classified as *grasslands*, after the dominant forms of plant life—the short, tall and mixed grasses—flourishing in this semi-arid region. Over time, these grasses have modified and enriched the soil and evolved root systems to make the most of the earth's available moisture.

Climatically, the prairies only receive between 300 and 500 millimetres of rain (12-20 inches) annually, mainly in the early spring and summer. The reasons for this lack of moisture tower in the sky at the region's western edge—the Rocky Mountains. Prevailing westerly winds, humidified and warmed by the Pacific Ocean, lose much of their moisture as they are forced up and over the continental divide. Once past the mountains, the winds are warmed and dried. It is these winds that are largely responsible for *soil moisture deficits*, a condition where the amount of evapotranspiration exceeds precipitation.

It is the mountains, however, that supply most of the region's surface water via the North and South Saskatchewan Rivers and their tributaries. In Saskatchewan and Manitoba, the Qu'Appelle, Souris and Red Rivers generate the balance. Throughout the prairies, there is a noticeable dearth of natural lakes. Thus, rivers comprise virtually all the surface water upon which the region depends. Prairie rivers originating in the mountains tend to have sustained flows all year round, although volumes are considerably reduced in late summer. Those rivers that arise on the prairies, however, are prone to extreme flow variations, flooding after a summer storm then drying up a few days or weeks later. To further illustrate, in very dry years, the flows of the mountain-fed Oldman and Red Deer Rivers of Alberta are about 40 per cent of the average annual amount, whereas in the Souris and Qu'Appelle, flows may be only three per cent of the average annual amount.

Drought

Despite the lack of precipitation, and uncertain river flows, the richness of the soil and favorable growing season enticed settlers to the region in the late 1800s. Native grasses were supplanted by grain crops that, in most years, did well. But the prairies are subject to pronounced dry spells, and wheat, oats, barley and rye do not have the kind of root structure that will hold the soil together and retain subsurface moisture. Consequently, when the rains all but stopped during the 1930s, farmers not only lost their crops but tonnes of topsoil.

The prairies are still subject to drought, and even at the best of times, the margin between water supply and demand is narrow. Nowhere is this more evident than in

the *Palliser Triangle*, a 20-million-hectare tract of southern Alberta, Saskatchewan and Manitoba where near-desert conditions are not uncommon.

Photo Courtesy National Archives of Canada, PA 98853

Captian John Palliser described the western grasslands as "unfit for civilization or settlement". His views were contradicted a decade later by John Macoun, who described the prairies as a land of unbounding fertility. Macoun's views paved the way for the constuction of the Canadian Pacific Railway across the grasslands, but history has shown Palliser to have been right more often than Macoun.

The region was first explored by Captain John Palliser, who described the southern plains to the British government as an "arid belt unfit for civilization or settlement". On the other hand, John Macoun, a Canadian naturalist, saw the area as the "garden of the whole country of unsurpassed fertility". Widely divergent views—but both were correct. Palliser saw the land in the middle of a drought, whereas Macoun travelled across during one of the wettest periods in recorded history. Macoun's assessment convinced John A. Macdonald that profits from the sale of prairie land could underwrite the cost of a transcontinental railway.

Vagaries in the weather and streamflow still plague residents of the Triangle. In 1976 and 1977, and again in 1981, 1984, 1985 and 1986, drought paid a visit. Drought may be one of two kinds: an *agricultural drought*, where soil moisture becomes depleted, and a *water drought*, where water levels in streams, lakes and aquifers are abnormally low.

The drought of 1988 was both, and, in the opinion of many prairie farmers, the worst. The Red River Valley of Manitoba, one of the province's richest farmlands, was ravaged by hot, dry winds which ripped away topsoil and dried up water supplies. Thirty-four communities faced water shortages and farmers waited for up

to three hours at government wells to fill their tank trucks. Rosetown was one of the hardest-hit areas in Saskatchewan. Fields that had generated 25 bushels per acre in 1987 with only 125 millimetres of rain yielded just five bushels with the virtual absence of fall precipitation, winter snow cover and summer rains. In Limerick, Saskatchewan, people went on voluntary rationing to preserve the village's water supply, which normally is replenished by snow melt. As local reservoirs were depleted, the village resorted to piping water from a gravel pit ten kilometres away to fill them. The $76,000 cost of pumping was shared by the Saskatchewan Water Corporation and the Prairie Farm Rehabilitation Administration (PFRA), but Limerick still paid $17,000 of the bill. As a result of this and other measures, village residents are paying $67 per 35 m^3 of water, a rate nearly four times the national average and one-and-a-half times the provincial average. Nor was the situation any better in Assiniboia, where people caught watering lawns during the hot, dry summer faced a $500 fine and having their water shut off for 48 hours.

In Alberta, precipitation was only about 40 per cent of its normal average during the winter of 1987-88. As a result, there was almost no spring runoff to replenish the dugouts and sloughs that cattle and other livestock use as drinking water. Lethbridge recorded no measurable rainfall in April, something which had never happened during the previous 86 years, and in May, the area received less than half its normal rainfall. Swift Current, Saskatchewan, recorded 55 millimetres of precipitation from September, 1987, to the end of April, 1988, the lowest amount of rainfall for those months in 102 years. River flows were also down in the South Saskatchewan River, which carried only 28 per cent of its normal water levels from April to June. This, in turn, affected recreation at Coteau Beach on Lake Diefenbaker, where reservoir levels were down five metres, leaving boat owners high and dry.

Drought conditions during the 1980s also had a pronounced effect on groundwater levels. In dry years like 1981, 1984 and 1988, groundwater was simply not recharged, and wells that tapped shallow aquifers started to dry up. This was bad news for the 90 per cent of rural Saskatchewanians who rely entirely on groundwater, as well as for the 114 communities in the same position. During 1988, the Saskatchewan Water Corporation allocated $8.5 million for subsidized well drilling and dugout construction (the money covered half the cost of well drilling, dugout pumping and small reservoir construction, as well as half the cost of municipal water projects). As of August 19, 1988, the Corporation had received 2,467 individual applications, over 1,800 more than in all of 1987, and ninety-four for community well funding, up by 74 per cent from the previous year.

The answer to Saskatchewan's water supply woes may lie in deep aquifers. While these aquifers contain enough water to flood the province to a depth of 1.5 metres, their quality is suspect. Water from deep aquifers contains iron, manganese and magnesium, minerals which can stain bath fixtures, give water a poor taste and make soap hard to lather. The University of Saskatchewan has been

experimenting with injecting fresh water from spring runoff into the aquifers in an attempt to improve water quality.

A prolonged drought has social and economic impacts extending far beyond water supplies. With reduced crops, farmers are forced into debt and must depend more on government subsidies. Land values depreciate and, in some cases, farms fail. In 1988, the federal government estimated that the value of land and buildings had fallen by $2.6 billion since 1981, and banks and farm-credit agencies were holding more than 200,000 hectares of land repossessed from prairie farmers. Businesses that depend on the farm industry were also affected. One farm equipment dealer in Avonlea, Saskatchewan, reported a sales drop of 35 per cent in 1988, forcing him to cut his staff of thirty by ten. Farm equipment dealerships and agricultural processing industries across the provinces suffered similar fates during the 1980s. Wheat prices have also plummeted, in part because of a subsidy war between the United States and European Common Market countries. According to the Winnipeg-based Canadian Wheat Board, prices would have had to almost double to recoup farm income losses during 1987 and 1988.

Water Quality

Even without a drought, prairie rivers are not always able to satisfy the needs of communities they serve. The Qu'Appelle River, a major source of surface water in south-central Saskatchewan, is plagued by periodic low flows and water quality problems from agricultural runoff and municipal wastewater discharges. So pronounced are the nutrient loadings that the river and a number of lakes along its route are now considered highly eutrophic and therefore unsuitable as a water supply for two of the province's largest communities, Regina and Moose Jaw. Their alternative source of water is Buffalo Pound Lake, a shallow, man-made reservoir fed from Lake Diefenbaker via the Qu'Appelle River. Water from the lake is treated at the Buffalo Pound Water Treatment Plant, then piped to the two cities. But Buffalo Pound Lake is eutrophic, and suffers from excessive weed growth and a bottom coated with layers of dead and decaying organic matter. This foul-smelling water gave Regina the dubious distinction of being the 'bad-water capital' of Canada.

In 1986, a $15 million granular-activated carbon filtration system was installed at the Buffalo Pound Treatment Plant in an effort to improve the water's taste. While drinking water quality has improved, many residents feel that the system is merely a less expensive way of postponing the inevitable, a $150 million pipeline directly to Lake Diefenbaker. The pipeline has become a political football in Saskatchewan: the provincial government refuses to help fund a pipeline unless the City of Regina obtains federal assistance, but the federal government is refusing financial assistance, even if the city and province can raise half the money. This is ostensibly because federal money was used to develop Lake Diefenbaker in the first place.

Water Development on the Prairies

Given the history of water shortage on the prairies, it is not surprising that there has been considerable public pressure for government sponsorship of water development projects, and in particular, water storage. To this region, reservoirs mean a secure supply for municipalities, industries, recreation and, more than anything else, irrigation.

Early irrigation on the grasslands.

Irrigation in western Canada had its origins in the settlement accompanying construction of the transcontinental railroad. In return for building the line, the Canadian Pacific Railway was given $5 million and 10,125,000 hectares (25 million acres) of land. The land was originally designated as alternate sections along the right-of-way. Many of the sections in Ontario, British Columbia and Manitoba, however, were already privately owned. In compensation, the CPR received additional blocks of land in Alberta, which were destined to become irrigation districts.

Talk of irrigation was not particularly popular in the early days of western settlement, nor was irrigation seriously considered by the CPR and the federal government. The railway intended to make money from the transport of grain grown by new settlers. Initial harvests were promising, but by the mid-1880s, drought had set in, and by 1890, it had become acute. Spurred by discontented western farmers, the federal government passed the *Northwest Irrigation Act* in 1894. This legislation became a cornerstone for irrigation development because it transferred ownership of water to the Crown. (The prairies west of Manitoba at the time were federal lands. The provinces of Alberta and Saskatchewan were not

created until 1905, and the ownership of natural resources was not transferred until the 1930s.) In effect, the government could now negate existing riparian rights by diverting water to non-riparian lands and by granting water licenses to non-riparian users.

The federal government was hardly in the position to finance large-scale irrigation development, so it turned to private enterprise. The first corporate investment in irrigation was undertaken by Alexander Galt, on lands he had received for building a railway linking Lethbridge and its coal mines to the main line of the CPR. It was the CPR, however, that had the largest stake in western settlement, and the federal government eventually succeeded in convincing the railway to become involved in irrigation. Preliminary government surveys indicated that 810,000 hectares (two million acres) of land within the CPR block could be irrigated by diverting water from the Bow River at Calgary. The CPR, however, suggested that a Calgary diversion could only serve its western section, and that tapping the Bow at Bassano was required to irrigate its eastern section. A central portion was considered non-irrigable because of its rough terrain.

In the decades before and after the World War I, the CPR experienced difficulties in managing its Alberta irrigation projects. The company sold irrigable land for between $25 and $50 per acre and levied water rates of $1.25 per acre. Some farmers fell into arrears on their property and their water payments. The situation was worsened by the collapse of grain prices in 1921. As well, the CPR was losing money because its investment in irrigation was not being offset by increased freight traffic. Finally, in 1935, the railway turned the land and irrigation system of its eastern block over to local farmers, who then formed the Eastern Irrigation District. Several years later, the Western Irrigation District was established after a similar transfer.

As this transition was taking place, government began to take a more active role in irrigation. In 1946, a provincial crown corporation was set up to administer the St. Mary's and Milk River development, and in 1950, the federal government purchased holdings in what is today the Bow River Irrigation District. It was also during the 1950s that both governments built or enlarged several irrigation reservoirs and constructed canal systems to deliver water to Alberta's southwest corner. In 1973, the federal government discontinued its involvement in irrigation. Since that time, the Alberta government has assumed ownership and operational responsibility for all of the federal systems and has provided a large measure of economic and policy support for continued expansion of irrigation in the province.

Irrigation development in Saskatchewan has proceeded at a much slower pace. Private companies such as railways were unwilling to risk developing the heart of the Palliser Triangle. It was not until the severe droughts of the 1930s that the federal and provincial governments, in their attempt to save and rebuild western farming, constructed irrigation systems in the drought-prone areas of the province.

Most of the present irrigation in Saskatchewan has been developed under the auspices of the Prairie Farm Rehabilitation Administration. This federal agency, in conjunction with the province, constructed 26 storage reservoirs which today provide water to approximately 650 farmers. In 1958, PFRA began construction of the Gardiner and Qu'Appelle Dams which ultimately created Lake Diefenbaker, a huge reservoir with a storage capacity of 8.9 million dam^3 (roughly equivalent to the average annual flow of the South Saskatchewan River). The project was completed in 1968 at a cost of $120 million, and has fostered irrigation development of an additional 18,000 hectares near Outlook, Saskatchewan. In total, some 70,000 hectares (173,000 acres) of land are irrigated in the province.

Social and Economic Benefits of Irrigation

Irrigation can provide water for crops year after year, regardless of natural precipitation shortfalls, and its greatest benefit is the protection it provides against drought. As well, irrigation allows the cultivation of high-return 'specialty crops', such as corn, sugar beets, potatoes and other vegetables. These crops require higher temperatures, more sunshine and a longer growing season than cereal grains or hay. Such conditions are present throughout the Triangle. Furthermore, crops grown under irrigation will likely produce higher yields than crops grown without irrigation (known as *dryland farming*), although yields vary with the type of crop, the amount of natural precipitation and how much fertilizer is applied to the land. Irrigation stimulates diversification on the farm because irrigated forage and grain crops also support herds of beef and dairy cattle. Even the carrying capacity of pasture can be enhanced by irrigation, although most irrigation water is applied directly to crops.

The value of irrigation becomes obvious when one compares an irrigated area with one that does not have irrigation. The Eastern Irrigation District in southeastern Alberta covers some 600,000 hectares. Of this, about 180,000 hectares is arable farmland, about half of which is irrigated within the District. Farmers grow eleven specialty crops as well as hard spring wheat, and the 30,000-head Lakeside Feeders is considered to be Canada's biggest feedlot. The EID supports a population of 18,000, including 10,000 in the Town of Brooks. Immediately north, in a climatically similar region, lie 800,000 hectares of land in the vicinity of Hanna, of which 280,000 are arable. There is very little irrigation here and the only significant cash crop is wheat. The area's population is 6,000, including 5,000 living in Hanna.

Nor are the benefits of irrigation restricted only to irrigation farmers. Irrigation districts in southern Alberta provide a potable water supply to 48 communities and a number of feedlots, food processing plants and enhanced oil recovery projects. Irrigation water also fills the dugouts of local dryland farmers and supports several wetland projects. Reservoirs that store water for irrigation can be used for recreation (camping, boating, fishing and swimming). One enterprising

businessman near Vauxhall, Alberta, produces cubes from locally-irrigated alfalfa crops and markets them to Korea and Japan. Add to this the agricultural service sector, and irrigation's contribution to the economy becomes considerable. Irrigated agriculture, although it is only carried out on four per cent of Alberta's 31 million improved farm acres, generates 15 per cent of the province's gross farm cash receipts. In 1981, the total economic benefits from irrigation accruing to the province were estimated at $941 million, or two per cent of the provincial gross domestic product. There are about 5,000 farm families in Alberta today who irrigate their land.

Other benefits are less tangible. For Alberta, and to a lesser extent Saskatchewan, irrigation is perceived to have raised the standard of living, affording rural people the same amenities that urban people enjoy—better educational facilities, medical care, recreational opportunities, and so on. A plaque in the town of Brooks proclaims that "water works wonders" and this mind-set is shared throughout Palliser's Triangle. With drought constantly on everyone's mind, the availability of water affords a lifestyle that was previously thought to be unobtainable.

The Cost of Irrigation

Despite the advantages and benefits of irrigation, the industry itself is not economically sustainable without public subsidies. Over the years, there has been a sizeable investment by government. Most recently, the province of Saskatchewan and the federal government signed a $100 million irrigation agreement to expand irrigation around Lake Diefenbaker by nearly 70,000 hectares. The government-funded Rafferty-Alameda project near Estevan, Saskatchewan, will support new irrigation of 12,000 hectares in addition to storing water for thermal power generation and flood control. And the Oldman Dam, west of Pincher Creek, Alberta, will allow an additional 69,000 hectares of land to be irrigated in the southern part of the province. In each case, those who benefit directly, the prospective irrigators, do not pay for the developmental costs for water, but only the delivery charges and the costs of irrigation equipment they will use on their own farms.

One of the reasons that irrigation is expensive is that the infrastructure is in constant need of repair. The conveyance system inherited by the newly-formed Alberta irrigation districts in the 1930s deteriorated badly over the years. Canals became overgrown with weeds and lost a good portion of their water through seepage. The condition of the *headworks*, where water was diverted from the rivers, also declined. Between 1970 and 1982, the Alberta government invested $104 million in a headworks rehabilitation program (most of the headworks were taken over by the province in 1973) and $146 million in an Irrigation Capital Works Program. The latter program is cost-shared with irrigation districts, with the government funding 86 per cent of the cost and the irrigation districts paying for the remaining 14 per cent—a ratio the Alberta government justifies as the relative

distribution of irrigation's benefits between farmers and the wider provincial economy.

Much of the remediation work within districts has been on the canals themselves. In some cases, the canals have been straightened and outfitted with drop structures to curtail erosion. More frequently, they have been lined with polyethylene sheeting or concrete to prevent seepage. A fairly recent innovation involves the installation of underground pipes which deliver water directly to the farm sprinkling system under pressure. Irrigation Capital Works Program funds have also been used for the construction of internal storage reservoirs and for automated control systems. The primary rationale for rehabilitation has been to modernize the irrigation distribution system and make it better capable of supplying water to district ratepayers. It is also likely that the systems are becoming more efficient because conveyance losses are being minimized or eliminated. The question of efficiency in irrigation districts is not a simple one, and there has been a good deal of debate about whether water is being wasted. To more fully understand the issue, some explanation of water distribution patterns is required.

When a farmer wishes to irrigate, he places an order for water with the district office. Water is then released from storage through canals to the farm gate. The farmer typically orders water 24 hours in advance, because it takes that long for water to reach his farm. In a large district with as many as 800 ratepayers and over 2,000 kilometres of canals, the scheduling of water releases becomes a major task.

Obtaining water from an irrigation district is roughly analogous to getting water from a stream every time one needs a drink or a bath, except that the flow of water in canals is controlled. There is always more water in the distribution system than is actually used, and the left-over portion, called *spill water*, finds its way into sloughs and ponds or to rivers as *return flows*. Other losses occur from evaporation and seepage. These system losses account for the fact that, on average, only 30 to 60 per cent of water diverted from rivers reaches the crop. By design, irrigation delivery systems are open-ended, rather than closed, and therefore are inherently inefficient.

The other aspect of efficiency is related to the application of water on the farm. Many farmers rely on experience rather than methods that determine actual crop needs. Consequently, some may actually over-irrigate. Moreover, there is little incentive for using less water because farmers pay a *flat* rather than *metered* rate. In fact, water is likely the least of their input costs, including energy, fertilizers and pesticides. The common use of sprinkler systems (estimated at 75 per cent in southern Alberta) also means high evaporative losses on hot, windy days. Sprinklers are designed to use less fuel, not less water, and the amount of sprinkling is more likely to be governed by the cost of pumping. In practice, however, most farmers tend to under-irrigate rather than over-irrigate. Although the reasons for this are not entirely clear, it is thought that not all farmers need to

obtain maximum crop yields to keep their farms economically viable, and that the cost of irrigation, in terms of energy and labour, does not always justify the optimal application of water to crops.

Another problem frequently identified with irrigation is *soil salinity*. Many soils in western Canada are *solonetzic*, that is, they contain salts that were present in ancient sea beds. When the pioneers removed the tough, thickly-rooted sod, salts could travel more freely between the surface and the water table. The upward movement of water brings salts to the surface. As the water evaporates, it leaves a white crust known to many western farmers as *alkali*. Salinity can occur in both irrigated and dryland farming areas, and is prevalent on the prairies. More than two million hectares are affected, and in some places, salinity is increasing by 10 per cent annually. In 1984, salinity cost farmers more than $25 per acre in lost or reduced crop yields.

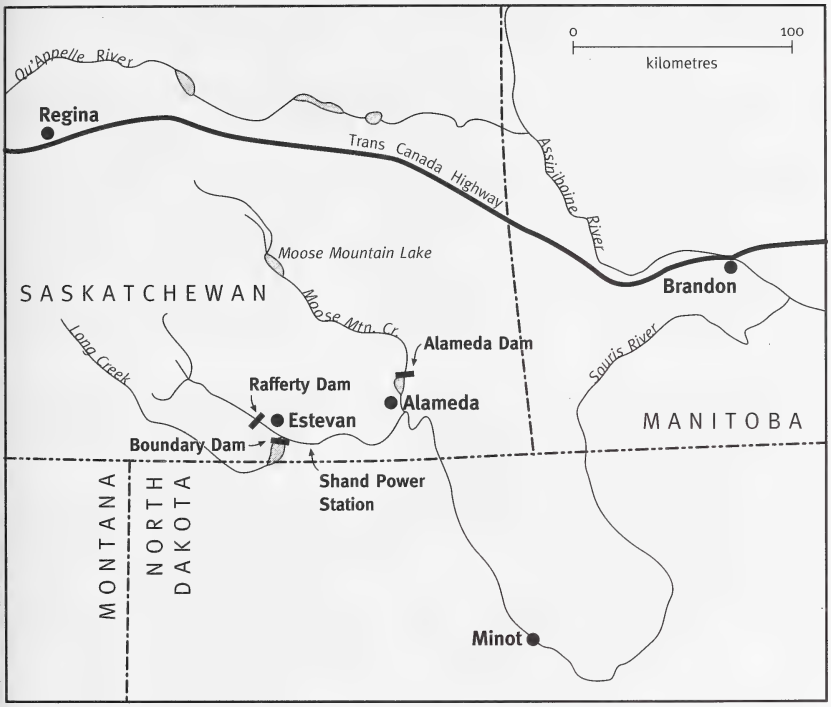
There are two known causes of salinization. One is the practice of summer fallowing, where land is left unplanted. Under summer fallow, water that would normally be used by plants percolates beneath the root zone, carrying salts with it. At some depth, the water meets an impenetrable layer and moves laterally, emerging in a low-lying area, or *seep*. Here, the water evaporates or is taken up by plants, leaving the salts behind. The other cause is irrigating on poorly drained soils. Water applications cause the water table to rise, again carrying dissolved salts upwards. Evaporation of the sub-surface moisture leaves a film of salts on the surface. About 100,000 hectares of irrigated land in Alberta have been affected in this manner.

Salinization can be controlled in irrigation areas by installing a sub-surface drainage system. Salts then can be flushed from the soil by heavy sprinkling. Drainage systems are costly (between $800 and $1,000 per acre) and discharge salt-laden waters into return flow channels, increasing the salinity of rivers. It is now standard practice to determine the irrigability of soils when a new irrigation project is proposed, and areas with solonetzic soils are usually not recommended for development.

Multi-Purpose Management

The need for water resource planning occurs when the quality and quantity of water is insufficient to meet current or projected demands and when there are unresolved conflicts among water users. Rivers pose a particular challenge for planners because they serve as a source of supply for many different users along their course. For this reason, planners have adopted the principle that river basins should be managed as a unit so that the needs of upstream and downstream users can be considered jointly and the benefits and costs of management options can be shared more equitably. One means of reconciling competing interests is to

design projects that are *multi-purpose*, that is, can satisfy several needs simultaneously.



Adapted from *The Rafferty-Alameda Project, Summary Report of the draft Initial Environment Evaluation*, Environment Canada

Figure 16: *The Rafferty-Alameda Dams Project–This controversial project in southeastern Saskatchewan became the focus of national attention when environmental groups forced the federal government into an environmental assessment.*

The southeast corner of Saskatchewan is one of the driest parts of the province. Estevan, the region's largest city, bills itself as the 'Sunshine Capital of Canada', and it's not unusual for summer temperatures to reach a scorching 45°C (113°F). Area farmers can remember long periods of drought, when the region's main source of water, the Souris River, was merely a trickle. But the river can also become a raging torrent, wreaking havoc as far downstream as Minot, North Dakota.

Although water management on the Souris River has been discussed off and on since the turn of the century, it was not until the mid-1980s that the province of Saskatchewan decided to build two dams—the Rafferty Dam on the Souris about six kilometres upstream from Estevan, and the Alameda Dam on Mouse Mountain Creek near the Town of Alameda. The difference this time was the promised

contribution from the U.S. government of $41 million in exchange for flood protection for North Dakota. The other part of the 'window of opportunity' was the decision by the Saskatchewan Power Corporation to build the Shand Power Station just south of Estevan. The thermalelectric plant would require water for cooling, and the only source of water for this purpose is the Souris River.

Supporters of the project see the $120 million project as the best way to solve the long-term water shortages of the region. Estevan and area businessmen have spent years lobbying for the dams, arguing that the city cannot attract new businesses without water. On the other hand, the project has raised the spectre of serious environmental and social impacts—increased strip mining, flooding of wildlife habitat, loss of agricultural land, and disruption to the lives of farmers and ranchers who depend on the valley. What happens in Saskatchewan is also of concern to Manitobans. They fear that the dams will alter the quantity and quality of water in the Assiniboine River, which receives the flow of the Souris as it winds its way back into Manitoba after passing through the state of North Dakota.

The Rafferty-Alameda case is of interest because it became the first instance in Canada where federal EARP guidelines were considered in a project which fell primarily under provincial authority. Saskatchewan had already done its own environmental assessment, as required by law. But because the Souris is an international river, the province also was required to obtain a licence under the *International Rivers Improvement Act* (a federal statute) to construct the dams. Initially, the licence was approved; however groups opposed to the project were successful in quashing the licence in federal court on the grounds that the Minister of Environment who, the court ruled, was required to use the EARP process, had failed to do so. With work on the project shut down by this court decision, the Minister instituted the first stage of EARP, an *Initial Environmental Assessment or IEE.*

In the EARP process, an IEE decides if a project should be sent for a full environmental review. In due course, the IEE recommended exactly that, noting the project's associated environmental impacts were sufficient to warrant further examination. Saskatchewan was outraged but accepted compensation from the federal government for the delay while the full review went ahead. The agreement had lasted just a few months when Saskatchewan restarted construction, claiming the federal government had agreed the project could proceed while the review was still ongoing. The federal government denied it, and the review panel resigned, saying there was now no point to their work. Powerless to stop the project without creating a major jurisdictional dispute, the federal government watched as the Rafferty Dam was completed in 1991. Alameda Dam was scheduled for completion in late 1992.

The importance of the Rafferty-Alameda court decision was that it forced the federal government into the assessment of other major provincial projects. One of these was the controversial Oldman Dam project in southern Alberta. Like Rafferty-

Alameda, this case became a byzantine tale of jurisdictional manoeuvring under the legal challenges of environmental groups. (See Study Five for a discussion of a second project affected by the Rafferty-Alameda decision, the Alberta-Pacific pulp mill project in northern Alberta.)

The Oldman Dam: A Case Study

The Oldman River drains a 16,157 square kilometre area of southwestern Alberta and contributes, on average, 36 per cent of the flow of the South Saskatchewan River within Alberta's boundaries. Over the years, the Oldman has served as a source of water for municipal and irrigation uses. The river also supports a productive cold-water fishery and is a popular recreational resource for hikers, canoeists and fishermen. Like other mountain rivers, the Oldman passes the majority of its flow during the spring, and water levels in the late summer have historically been low.

The largest water user along the Oldman River is the Lethbridge Northern Irrigation District (LNID). The District withdraws water at Brocket on the Peigan Indian Reserve, and distributes it to 800 farm families. Operationally, the LNID fills several off-stream reservoirs when spring flows in the river are high, and releases water from storage later in the summer. Usually, the combination of offstream storage and river withdrawals is sufficient to meet the water requirements of LNID ratepayers. Problems occur when river flows are abnormally low and rainfall is minimal. During the last decade, the LNID has been forced to shut down several times when these conditions occurred simultaneously. The St. Mary's River Irrigation District (SMRID), immediately south of the LNID, diverts water from two Oldman tributaries (the Waterton and St. Mary's Rivers) and does not depend directly on the Oldman as a source of supply. The SMRID, however, must release a portion of its storage from the Waterton and St. Mary's Reservoirs to maintain minimum flows in the Oldman downstream from the Brocket site.

The discrepancy between water availability and water demand is perceived to be the major problem in managing water in southern Alberta: flows are high in the spring when demands are low, and low in the summer when demands are high. Demand in this context refers mainly to irrigation requirements, because irrigation in the Oldman Basin accounts for 99 per cent of all water consumption. There is little industry in the basin, and the two large municipalities that draw from the Oldman have seldom had any water supply problems. The City of Lethbridge has estimated that demands can be adequately met for the next thirty years; this community is concerned, however, that flows in the Oldman may not be adequate for sewage dilution. Fort McLeod has had instances of water rationing when flows were low; this may, however, have more to do with an old water distribution system subject to leakage.

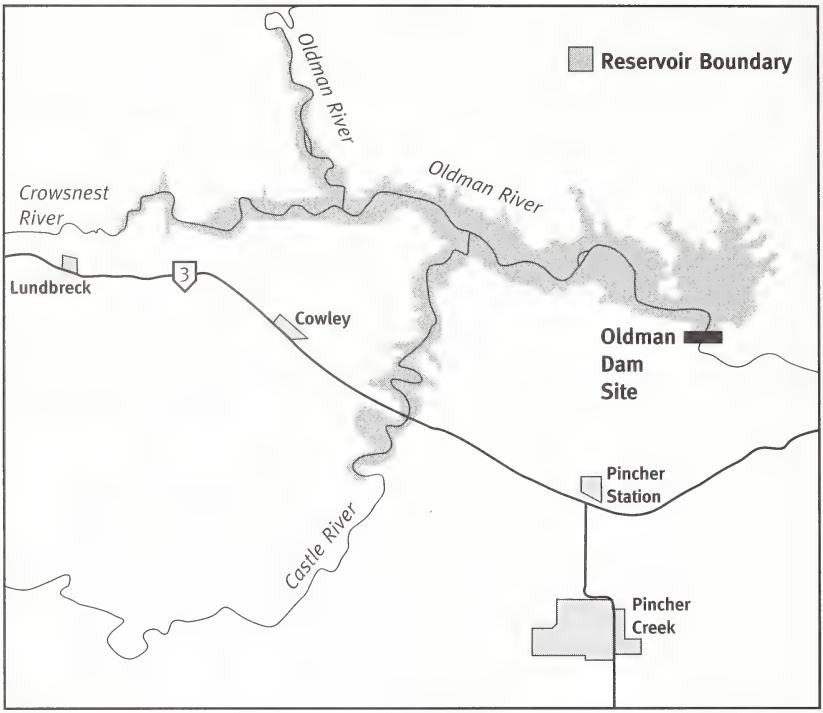


Figure 17: *The Oldman Dam and Reservoir–The Oldman Dam, built at a cost of more than $350 million, will store nearly 500,000 dam³ of water, enough to irrigate an additional 69,000 hectares of land in Southern Alberta. Its construction was bitterly opposed by environmental groups.*

A second factor affecting supply and demand has to do with Alberta's commitment to interprovincial apportionment. Although the province is required under the Master Apportionment Agreement to pass 50 per cent of the South Saskatchewan's flow to Saskatchewan, it has, since 1969 when the Agreement was signed, passed an average of 83 per cent to its eastern neighbor. This is because Alberta lacks the storage capabilities to hold back the 'excess' water. The province is also required to maintain minimum flows at the border of 42m³/s; however it is unlikely that this provision has ever been violated.

Finally, there has been a growing demand for irrigation development in the region. In 1920, 72,000 hectares of land were irrigated in the South Saskatchewan River Basin. By 1980, this figure had reached 352,000 hectares (see Table 6.1). Although 3,200,000 hectares (8 million acres) of land in the South Saskatchewan Basin are suitable for irrigation, only about 700,000 hectares (2.1 million acres) could be irrigated with the available water supply. Nevertheless, this represents an increase

of about 50 per cent over current or planned levels. Given the frequency of drought within the Palliser Triangle, such an interest in irrigation is understandable, and irrigation to communities like Hanna would undoubtedly afford considerable social and economic benefits. Pressure for expansion has also come from irrigation districts, who have both the irrigation infrastructure and the political clout to bring it about. What they lack is water.

Table 2: Growth of Irrigation in the South Saskatchewan River Basin

Year	Irrigated acreage (hectares)	Percent increase over previous decade
1920	72,000	–
1930	136,000	88%
1940	206,000	51%
1950	222,000	7%
1960	282,000	21%
1970	298,000	5%
1980	394,000	32%

Source: *Summary Report, South Saskatchewan River Basin Planning Program*, Alberta Environmental Protection

The idea of storage on the Oldman River was conceived during the 1960s, but it was not until 1974, after a comprehensive study on the Oldman River Basin, that the government of Alberta decided to actually construct a dam on the river. At the time, the provincial government's policy on water management stated that additional regulation of the South Saskatchewan system would be required to meet future water demands for irrigation, industrial and other uses. The announcement of the dam touched off considerable controversy, and a second Oldman study, under the auspices of the Oldman River Study Management Committee, was initiated to make recommendations for water management in the Oldman Basin, incorporating the concerns of area residents. As a follow-up, the Environment Council of Alberta (ECA) was given the mandate to conduct public hearings throughout the Basin and to make its own report and recommendations to the government.

During the hearings, there was a great deal of support for assuring a more dependable supply of water for irrigation. The question was how this should be done. Two alternatives to on-river storage were suggested: a continuation of irrigation rehabilitation, and additional off-stream storage capacity. Improvements in efficiency brought about by rehabilitation would, according to some, make water available to irrigate additional acres without having to take more water from the Oldman River. Alternatively, increased off-stream storage would lessen the dependency on river withdrawals during the late summer. The ECA estimated the cost of continued rehabilitation and additional offstream storage to be between $258 and $303 million. Irrigation efficiency, in the ECA's opinion, could be

improved to 75 per cent through metering and through a pricing system encouraging more efficient use of water by farmers.

In the end, the Alberta government opted for on-stream storage, but did not identify the site for another six years. In 1984, plans were announced to construct a dam on the Oldman River at the Three Rivers site, so called because it is located near the confluence of the Oldman, Castle and Crowsnest Rivers. Two other sites had been considered but judged unsuitable: the Fort McLeod site was too far downstream to serve the LNID, and the Brocket site on the Peigan Reserve was considered too expensive. It is also likely that the Peigan site was rejected because the dam would have been on reserve land, making the question of ownership uncertain.

The dam will store 493,000 dam^3 of water, or about 14 per cent of the mean annual flow of the Oldman River, and will allow an additional 69,000 hectares (170,000 acres) to be irrigated in the Oldman Basin. Estimated at $200 million in 1984, its final cost will be more than $350 million. Of all three sites, Three Rivers will result in the greatest amount of community disruption, a fact identified in previous studies. 5,800 hectares will be flooded and 20 viable farming operations eliminated, with another 14 seriously affected. As well, the Castle and Crowsnest Rivers, attractive to hunters, fishermen and canoeists, will be inundated and a number of Blackfoot archaeological sites will be destroyed.

The Alberta government's position on the Oldman Dam is that expanded crop production and economic diversity can only be achieved in southern Alberta through irrigation. The Oldman Dam will permit flow regulation and on-stream storage for municipal and recreational use and irrigation expansion; it will allow the province to better meet commitments to downstream provinces with respect to maintaining minimum flows, and it will create considerable economic benefits for local communities. The government estimates that irrigation of the 69,000 hectares will result in a $42 million net annual increase in the value of agricultural production and the creation of up to 1,700 jobs in the region. As well, the project is expected to inject about $77 million into the local economy during construction and create 2,100 person-years of employment.

The loss of fish and wildlife habitat has been a frequent criticism of the Oldman project by environmental and recreational groups. Construction of the dam will interfere with the spawning migration of rainbow trout. As well, flooding of the upper Oldman, Castle and Crowsnest Rivers will have an impact on fish habitat. The Alberta government has established the objective of no net loss of recreational fishing opportunities, and has been exploring mitigative measures aimed at increasing fish populations by providing cover and nesting areas. Wildlife habitat will also be lost during construction and flooding. The government plans to establish additional habitat, including wetlands and nesting islands in the reservoir.

Although the Oldman Dam is viewed by the province as a multi-use project, its primary purpose is to allow irrigation expansion in the Oldman Basin. In addition to ameliorating water supply shortages, the Dam will promote economic diversification in a province that has, for the past fifty years, depended heavily on oil and gas development. At issue is whether the dam is necessary, or whether other methods might have sufficed to reduce obvious shortfalls in irrigation supply. The ECA has argued that a combination of efficiency improvements, pricing and off-stream storage would have allowed modest development without on-stream storage. The Alberta government has maintained that the dam was needed to offset shortages and that efficiency is a long-term commitment. While the government is continuing rehabilitation, its program appears to be aimed more at controlling seepage and salinization and improving water delivery than conserving water. The government, while adopting many of the ECA's recommendations, did not support a unit pricing system that would charge irrigators for what they used rather than a flat rate based on acreage. In addition, the Alberta Resources Commission, in its report to the government following public hearings in the South Saskatchewan Basin in 1984, also recommended that a per unit price system be considered as a conservation measure and a means of assuring equity for all efficient farmers. This and other recommendations are still under review.

Another question raised by the Oldman Dam has to do with balanced regional development. Over half the crops grown on irrigated land in Alberta are cereal and forage crops. These crops compete directly with those grown on non-irrigated land, yet dryland farmers, who have struggled through successive years of drought, do not benefit from the infrastructure subsidies given to irrigation farmers. While it can be argued that irrigation increases productivity and economic benefits to the province as a whole, a project like the Oldman Dam may benefit one part of the province at the expense of another. All three tributaries of the South Saskatchewan River system (the Oldman, Bow and Red Deer Rivers) contribute to meeting Alberta's apportionment commitments, yet there is no policy on how much water each should contribute, other than that the rivers should be managed "equitably and in concert". By constructing a dam on the Oldman River, more water from that river will be used for irrigation and less will be provided to Saskatchewan. During the South Saskatchewan hearings in 1984, this issue was recognized by many residents of the Red Deer Basin. They argued that the decrease in apportionment share from the Oldman River would have to be made up by allocating a greater percentage of the Red Deer River's flow to apportionment. This would diminish the possibility for irrigation development around areas like Hanna.

Opposition to the dam has been both vocal and active. A protest concert, headlined by Gordon Lightfoot, David Suzuki and a (briefly) reunited Ian and Sylvia, drew more than 8,000 people to a site on the banks of the Oldman River, upstream from the nearly completed dam. In an even more direct action, the Peigan Lonefighters Society attempted to divert the river around the dam, but they

were thwarted by police. As in the Rafferty-Alameda Project, the most productive battleground has been the courts.

In 1987 the Friends of the Oldman River Society (FOR) launched a court challenge over the validity of the licence granted to Alberta Environment under the auspices of the provincial Water Resources Act. The group was successful in having the licence quashed, but this decision was later overturned. FOR also petitioned the federal Departments of Transport (under the Navigable Waters Protection Act) and Fisheries (under the Fisheries Act) to use the EARP process. In this case, both requests were denied by the federal ministries on the grounds that the EARP guidelines did not apply. FOR then took their case to the Supreme Court of Canada, which ruled that federal jurisdiction applied under the licensing provisions of the Navigable Waters Protection Act.

Following this decision, the federal government conducted an environmental assessment of the Oldman Dam and in early 1992, its review panel recommended that the partially-filled dam be decommissioned because of its adverse environmental impacts. But the same panel gave the federal government an out, recommending that a series of mitigation measures be taken if the dam wasn't decommissioned. Not surprisingly, the federal government chose these alternatives rather than enter another jurisdictional battle with the Alberta government.

The court challenges by FOR have strengthened the resolve of southern Alberta farmers and municipalities to see the dam finished. The Southern Alberta Water Management Committee, formed in the late 1980s, has continued to argue that water storage is vital to their interests, and has resisted any effort at further environmental review. FOR, on the other hand, plans to argue that dam construction violates the federal Fisheries Act and that funding for mitigation by the province has been curtailed.

The cases of the Rafferty-Alameda and Oldman Dams illustrate the difficulty of building large water storage projects where there is strong public opposition. Conceived in the 1970s when water storage was the favoured means of encouraging economic development, both projects have come under attack in the face of growing environmental awareness and changing societal values. The public now is demanding that the full environmental consequences of a project be considered and mitigation identified before political and financial commitments to a project are made. When this does not happen, opposing sides become polarized and conflicts continue for years.

The two cases also demonstrate how environmental assessment has become an after-the-fact tool for citizen and environmental groups opposed to dams and other projects perceived to be environmentally damaging. The original intent of the process—to determine in advance whether or not a project should proceed on

environmental grounds—becomes subverted when governments announce projects before subjecting them to a proper environmental assessment and legitimate public review. Given the economic and political attractiveness of water development projects and the authority given provinces over their own resources, environmental assessment applied provincially does little more than determine mitigative measures for correcting the damage that the project will cause. On the other hand, the decision by the federal government to use EARP when projects are nearing completion is totally contrary to the intent of environmental assessment and only serves to further polarize the proponents and opponents of a project.

The *Canadian Environmental Assessment Act* is intended to solve the problems encountered by the federal government under the EARP guidelines. Its passage was prompted by pressures from environmental groups to reform the EARP process and by court challenges during construction of the Rafferty-Alameda and Oldman projects. In principle, it is intended to eliminate the duplication of federal and provincial environmental assessments and to co-ordinate the review of potential environmental impacts during the project planning stage. Given the history of provincial intransigence toward federal intervention in what are perceived to be provincial affairs, the new legislation may not be enough to harmonize the intentions of both levels of government. On the other hand, the provinces are beginning to re-examine their own regulations with respect to environmental assessment to bring them more in line with the federal initiative.

Study Seven: Water Development in the North

For many Canadians, the North conjures up images of a vast, frozen wasteland characterized by eternal winter darkness and icy temperatures. Yet the region is rich in resources—timber, wildlife and minerals—and, unlike the rest of Canada, is traversed by rivers and lakes that are still relatively pristine. This is not due to any wisdom or foresight but to a small population base and very limited industrial development. Despite its inaccessibility, the North holds a storehouse of resource wealth that could supply the rest of the country well into the next century.

The 'North' is generally referred to as that part of Canada beyond the 60th parallel encompassing the Yukon and Northwest Territories. In this study, however, we will consider the North to include the upper parts of all provinces from British Columbia to Labrador. This distinction is both social and geographic. Some northern rivers like the Mackenzie have watersheds that extend far south of the 60th parallel. In addition, the region is characterized by biophysical features influencing water quality, runoff patterns, river flows and the availability of groundwater. The region also contains the highest concentration of indigenous people who still rely on hunting, trapping and fishing (all water-related pursuits). These three features have a considerable bearing on the future management of water in the North and the controversies surrounding past water management decisions here over the past twenty years.

Biophysical Features

Precipitation in the North averages between 50 and 600 mm annually. A good portion of the precipitation occurs as snowfall (up to 80 per cent). A predominant feature of the North is *permafrost*, a layer of frozen ground beneath the surface that accentuates runoff and limits the recharge of groundwater. Permafrost is *continuous* in the more northerly areas, but *discontinuous* (broken) further to the south. Permafrost varies in depth depending on air temperature.

Water quality is affected by a number of natural processes endemic to the region. Northern waters originating in or flowing through the Canadian Shield have a lower buffering capacity (they have less dissolved calcium carbonate and other alkali salts, an important factor in their ability to neutralize acid inputs) and higher levels of naturally-occurring heavy metals such as mercury. Low temperatures in the North slow down the decomposition of organic materials, and for this reason it is generally believed that northern waters have a lower assimilative capacity than southern waters. Rivers also carry high sediment loads, particularly during spring runoff. These factors diminish the suitability of surface waters as a source of municipal and domestic supply and make them more susceptible to pollution.

Another influence on northern rivers is ice. Although other Canadian river systems are subject to winter ice conditions, the duration and effect of river ice is more pronounced in northern rivers, particularly the Mackenzie. This river remains frozen from early October to mid-July, restricting navigation. At spring break-up, ice jams may block the flow of water in the Mackenzie and its tributaries, the Peace and Athabasca, causing extensive flooding such as occurred in Peace River and Fort McMurray in the 1970s.

The northern river systems of Canada contain some of the richest habitats on the continent. Caribou, fur-bearing animals and numerous types of waterfowl are found along the western-flowing streams of northern Québec and the Churchill River of Northern Manitoba. It is the Mackenzie system, however, which offers the greatest diversity of plant and animal life. Wood Buffalo National Park on the Slave River supports the largest free-roaming bison herd in North America, and the only known white whale population in the western Canadian arctic visits the warm estuarian waters of the Mackenzie each summer to calve. The Peace-Athabasca Delta in northern Alberta is the largest freshwater delta in North America and, along with the Mackenzie Delta, is a breeding and staging area for millions of birds that migrate from the summer climes of the arctic to wintering grounds of the southern U.S. and Caribbean.

Jurisdictional Issues

The water resources of northern B.C., Alberta, Saskatchewan, Manitoba, Ontario, Québec and Newfoundland are under the jurisdiction of the respective provincial governments, who have the responsibility for managing them. In the Yukon and Northwest Territories, water is managed by the federal government. In 1971, the parliament of Canada passed the *Northern Inland Waters Act*, which, among other things, established water boards for each territory. These water boards issue licenses for water use and waste discharges, subject to approval by the Department of Indian Affairs and Northern Development (DIAND), the federal agency which administers the Act. (The division of the Northwest Territories into autonomous regions may influence the way federal policies in the North are carried out.)

This makes for a jurisidictionally-complex situation for the Mackenzie River Basin as there is no overriding authority. While the federal government has the responsibility to manage water in the territories, the major tributaries of the Mackenzie—the Peace, Slave, Liard and Athabasca—fall under the jurisdiction of British Columbia, Alberta and Saskatchewan. At the present time, there is no consensus among these parties on how water should be managed in the Basin, nor is there any agreement similar to the Master Agreement on Apportionment that governs prairie rivers. Everyone, including the territorial governments, admits that there should be such an agreement, as well as an interjurisdictional authority,

because developments on the tributaries will affect both the quantity and quality of water flowing across the provincial-territorial border.

The other major jurisdictional issue has to do with aboriginal rights. The *Constitution Act* gives parliament the exclusive power to enact laws dealing with Indians and lands reserved for Indians, and it is generally thought that this legislation would prohibit provinces from constructing works, such as dams, on Indian land without the consent of the federal government and the natives themselves. If a body of water is located on a reserve, however, it is not clear that the water or even the bed of that waterbody is actually part of the reserve. In Alberta and Saskatchewan, reserves were created before the provinces. Whether provincial water law diminishes riparian rights in force at the time is still uncertain.

Even more muddled is the question of aboriginal rights on lands not specifically defined by treaties. On the prairies, treaties were negotiated to make way for western settlement, but similar settlement pressures have not yet occurred in the North, where native groups have continued traditional lifestyles. In recent years, the development of natural resources in the North has prompted natives to assert their aboriginal rights to both the land and the associated water resources. The federal government has recognized the native peoples' aboriginal interest in water, but regards the water itself as part of the public domain, as do the provinces.

The conflicts between aboriginal rights and northern water development may lie in the perceptions Canadians in the south have about the North. The population base and centres of political power reside in what might be termed the country's 'heartland', while the resources that are needed for continued growth and development are in the 'hinterland'—the vast and unsettled northern region. What results is a view that northern resources are there to be exploited for the benefit of the entire nation, and that economic values and increased standards of living are the predominant considerations in planning.

This position was elucidated by the premier of Québec, Robert Bourassa, in his book *Power From The North*, in which he stated that development of the hydroelectric potential of Québec's rivers would require the "conquering and taming of the north" in order to provide cheap electricity to the province and the northeastern United States. Bourassa, it might be added, saw Québec as a "vast hydroelectric power-plant-in-the-bud" that was losing millions of potential kilowatt hours each day in river flows to the sea.

Economic development is also justified by those non-native Canadians who perceive native values as irrelevant and unimportant, and impediments to progress. On the other hand, living in rural villages and subsistence hunting and fishing is, for natives, part of their sense of who they are, and the maintenance of natural water conditions is one of the keys to the survival of their culture. This issue will likely become even more important as the federal government grants more autonomy to native groups.

Development Pressures

Mining makes a major contribution to the economy of the Yukon and Northwest Territories. At the present time, deposits of gold, silver, copper, lead, zinc and uranium are being extracted in the Mackenzie Basin. The greatest potential hazard from mining is the toxic contamination of surface waters from extraction and processing of these minerals and the disposal of mine tailings. Long after a mine is abandoned, tailings may continue to leach into the environment, posing a threat to fish and wildlife. Of particular concern are the radioactive wastes from uranium mines.

Gold was the magnet that attracted fortune-seekers to the Yukon at the turn of the century, and modern-day prospectors continue the quest, albeit with different methods. Placer mining uses water under pressure to dislodge and screen large quantities of mud. In 1984, there were 278 active licenses for placer mining, representing 90 per cent of all water licenses in the Yukon for that year. The practice can have a major impact on fish because streambed habitat is severely disturbed. Proposed new regulations for placer mining will restrict stream siltation but will not require the restoration of disturbed habitat.

By far the largest pressure for development has come from hydroelectric power generation. The North, with its substantial river flow, has a hydroelectric potential exceeding current production in the rest of the country. During the past two decades, major facilities have been constructed at Churchill Falls (Labrador), on the La Grande River of Québec (James Bay Project) and along the Churchill and Nelson Rivers in northern Manitoba. The W.A.C. Bennett Dam on the Peace River in British Columbia was completed in 1968. Further to the west, Alcan (Aluminum Company of Canada) built a hydro facility to generate electricity for its smelter south of Kitimat, B.C. In all cases except the Bennett Dam, water was diverted from one river to another to augment natural flows.

Hydroelectric development in Canada has been widely perceived as the answer to the energy 'crisis'. According to those who promote it, oil is too costly, nuclear energy is too dangerous and coal-fired plants cause air pollution and contribute to the greenhouse effect. Hydro power, on the other hand, is clean, uses a renewable resource and, once capital costs are recovered, produces electricity for consumers at a rate lower than for other sources. What hydro power enthusiasts do not always like to mention is that large-scale projects have had major impacts on the environment and on the economic and social welfare of native communities.

When the British Columbia government built the Bennett Dam, there was little if any consideration given to the impacts it might cause further downstream. The filling of the Williston Reservoir between 1968 and 1971, however, reduced flows in the Peace River and consequently—in a perfect but tragic demonstration of water's role in the maintenance of ecosystems—altered flooding in the Peace-Athabasca Delta 1,100 kilometres to the east.

Source: Peace-Athabasca Delta Summary Report, 1972

Figure 18: *The Peace-Athabasca Delta–The Peace-Athabasca Delta, one of the world's largest freshwater deltas, is home to millions of migrating birds and to dozens of mammals, including mink, otter, moose and bison. The damming of the Peace River in British Columbia affected water levels in the Peace-Athabasca Delta, nearly 1,200 kilometers downstream (see Figure 18a).*

For thousands of years, this World Heritage wetland has been maintained by periodic spring flooding caused by ice jams at the confluence of the Peace River and Rivière des Rochers, which drains Lake Athabasca. The ice jams would back up the flows of both rivers and make them spill across thousands of hectares of delta. This intermittent flooding maintained the delta in a primary state of succession, creating one of the most productive wetland areas in the world.

But with flows in the Peace River reduced by filling of the dam (at a time when there were already lower than normal water levels in the Peace) the ice jams didn't occur and there were no floodwaters to replenish the delta. As a result, the wetlands began to dry out and the natural process of species succession took its

course. Native species of grasses and aquatic plants were supplanted by shrubs and dryland plants that didn't support the existing delta wildlife. It was a disastrously unpredicted consequence, and the result was to tear away the social and economic underpinnings of the native communities at Fort Chipewyan on Lake Athabasca. The delta was their traditional trapping and hunting ground and they depended on its productivity for food and cash income. Their first direct knowledge of these changes was an inexplicable decline in water levels both in the delta and in the lake.

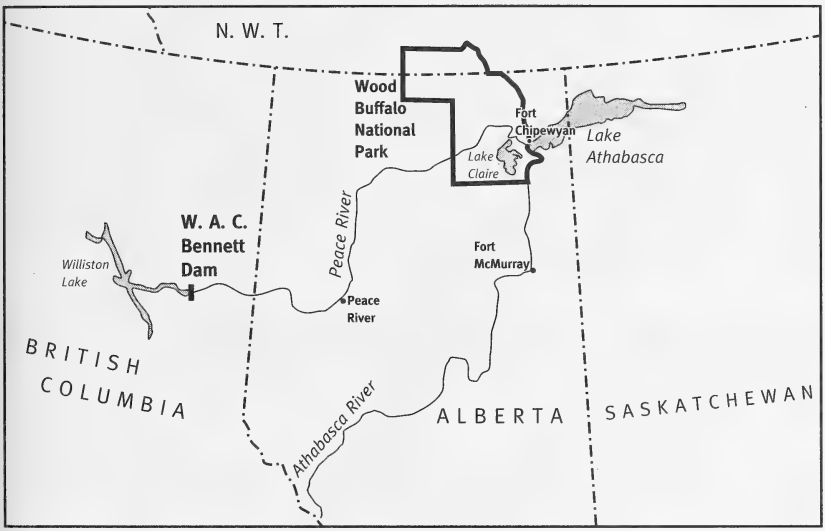


Figure 18a *The Peace River and location of W.A.C. Bennett Dam.*

To give an idea of the impact, the filling of the reservoir exposed 50,000 hectares of mud flats and reduced the shoreline and water surface area of the delta by nearly 40 per cent. The federal and Alberta and Saskatchewan governments attempted to contain the damage by building control weirs across Rivière des Rochers and a smaller delta river. The aim was to stabilize levels in Lake Athabasca and to mimic the flooding effect of ice jams, and thus maintain at least part of the delta. But recent studies indicate that these weirs have not performed as well as expected. The delta continues to decline and projections are that less than a quarter of the delta's historic area will be maintained. There was no compensation to Fort Chipewyan natives for lost income from hunting and trapping.

The diversion of water for the Alcan smelter in northwestern British Columbia produced effects that were much different. Aluminum smelters need large amounts of electricity, and to provide the necessary power, Alcan obtained a licence to construct the Kenny Dam on the Nachako River, and to divert a portion of its flow

through a 16 kilometre tunnel to its power plant on the Kemano River. The rising waters of the Nachako created a 960 km^2 reservoir, flooding the hay meadows of the Cheslatta Band who lived along the river. Records indicate that Alcan met with the natives only three times before the waters began to rise. Three weeks later, the company agreed to compensate each flooded family and assist in their relocation. It took DIAND another seven months to approve the sale of Indian lands that had been flooded.

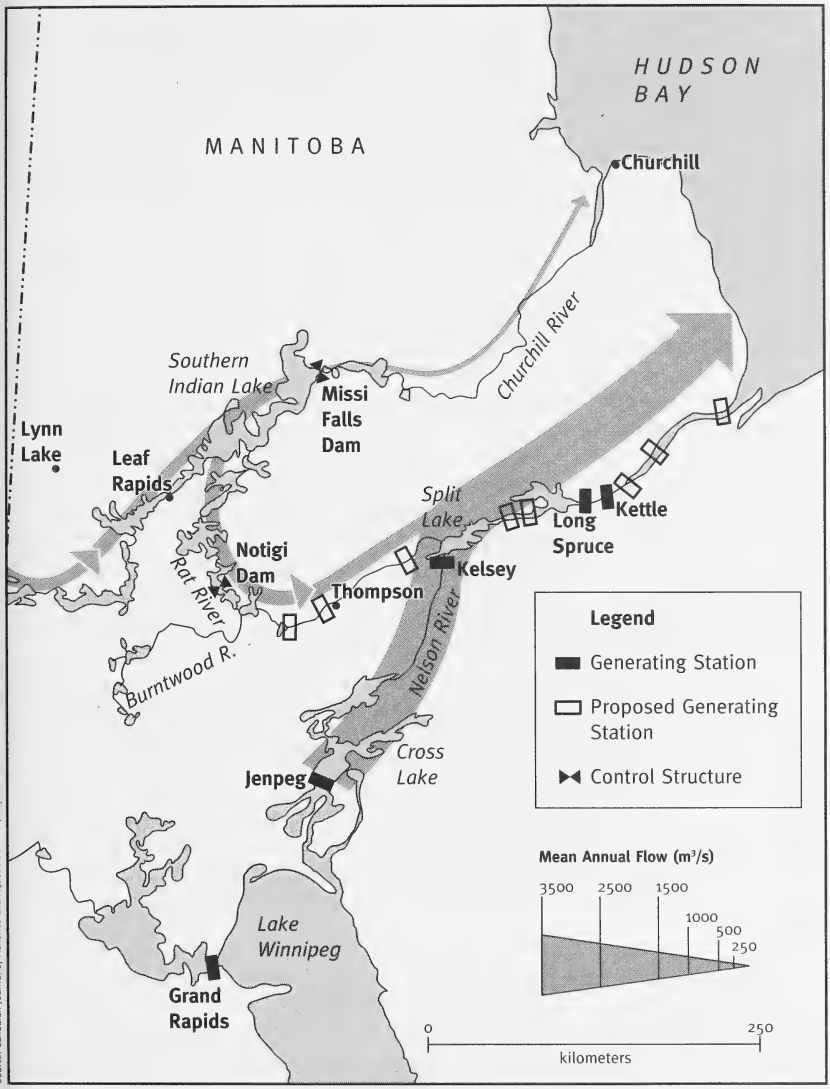
For twenty years following the construction of the smelter, there was enough water for energy production at Kemano and for the fish in the Nachako River downstream from the diversion. In 1979, however, Alcan needed more water from the Nachako to expand aluminum production. Unfortunately, reducing flows in the Nachako would mean severe impacts to the chinook and sockeye salmon populations that spawned in the river's headwaters. After years of fruitless negotiations with Alcan, the federal Fisheries Department finally took legal action against the company under the provision of the Fisheries Act. In 1987, an agreement was reached between Alcan and the federal and provincial governments to provide adequate flows for the fishery. But the settlement was still contentious, and as of early 1993 the dispute was still dragging on.

Impacts of Hydroelectric Development: Two Case Studies

Southern Indian Lake

Southern Indian Lake is located on the Churchill River in northern Manitoba, some 800 kilometres from Winnipeg. About 200 kilometres to the southeast is the Nelson River. Both rivers originate in Alberta and flow in roughly parallel directions before emptying into Hudson Bay. Although each drains an extensive area, the height of land separating the two watersheds at Southern Indian Lake is low and very short, so short in fact that water could be diverted from the Churchill to the Nelson without too much difficulty, especially if one was interested in using the water to produce hydroelectric power.

The hydroelectric potential of northern Manitoba had been identified in federal water power surveys as early as the first decade of this century, but it was not until 1961 that the Kelsey Station was constructed on the Nelson River to supply the International Nickel Company mine at Thompson. By 1964, federal-provincial studies began to examine the feasibility of developing additional stations on the Nelson and Churchill. These studies identified nine dam sites on the Nelson, but did not recommend any on the Churchill because flows in that river were not considered sufficient to make hydro development economical. Instead, they proposed to augment Nelson flows with water diverted from the Churchill. The decision to proceed with full development of the Nelson was announced by the Manitoba government in 1966 in conjunction with a public campaign to stimulate electrical consumption and export power to the United States. At about the same



Source: Canadian Journal of Fisheries and Aquatic Sciences, Department of Fisheries and Oceans

Figure 19: *The Churchill and Nelson Rivers Hydroelectric Developement–Up to 75 percent of the Churchill River's flows were diverted into the Nelson River system to generate hydroelectricity. But raising levels levels in South Indian Lake led to massive shoreline slumping and the disruption of native lives.*

time, the federal government announced it would assist in the construction of two transmission lines to carry northern-produced electricity to the southern part of the province. By 1984, Manitoba had extended this system by constructing tie lines to the U.S., Ontario and Saskatchewan.

Southern Indian Lake (SIL) was earmarked by Manitoba Hydro as the most feasible point for diversion. Their plan advocated building a dam at Missi Falls on the Churchill at the outlet of the lake, and releasing the impounded flow into a diversion channel at the lake's south end. From here, water would be conveyed along the Rat and Burntwood Rivers and join the Nelson at Split Lake. The dam would raise the level of SIL ten metres (about 30 feet), and allow the diversion of three-quarters of the Churchill River southward, augmenting the Nelson River flow by some 30 per cent.

Initially, there was public resistance in Manitoba to the scheme because the utility's study had not considered the effect of the diversion on the ecology of SIL and on the Churchill and Nelson Rivers, or the livelihood of 8,000 native and 4,000 Métis people living along Southern Indian Lake and along the Nelson who engaged in commercial fishing. In response, Manitoba Hydro hired a consulting firm to assess the project's impact on SIL, and, based on the firm's findings, opted for a 'low-level' impoundment plan that would limit flooding to three metres. A second environmental impact study was begun by the Lake Winnipeg, Churchill and Nelson River Study Board. This study was still in progress when construction of the dam and associated structures commenced in 1976.

There had been no public hearings in Manitoba on the diversion, but after a change in government in 1972, the newly-formed Manitoba Environmental Council held a public meeting to discuss the low-level impoundment plan. The Council had no mandate to conduct public hearings, nor was there any indication from the province that public opposition would alter its decision to proceed. As well, most of the people at the meeting saw the diversion as a foregone conclusion, although at the time, Manitoba Hydro had not yet been granted a license for the project. The meeting is of interest, however, because of the diversity of opinion over the project.

In its opening remarks, Manitoba Hydro pointed out that the project was required to guarantee electrical energy for a province lacking oil and coal reserves, that no other alternative was economically viable, and that the project (estimated at $109 million) would provide employment for Manitobans. Everyone else at the meeting, however, opposed the development. The natives contended that the project would damage the fishery and threaten their traditional lifestyle. Other people, while agreeing in principle with hydroelectric expansion and the ensuing benefits to Manitobans, argued that the environmental consequences were not fully understood and, in fact, could be considerable. Alternatives to the diversion included delaying the project until a more complete environmental assessment had been completed, tying in with the Saskatchewan power grid to import needed

energy, and pumping water from SIL. This last suggestion was proposed as a means of saving the lake if circumstances changed (e.g. lower power demands).

In the end, the Commission recommended against building the project, but despite its findings, the province's position was clear. In a letter to the Manitoba Métis Federation read during the meeting, the Manitoba Minister of Mines and Natural Resources stated that the government would not be involved in 'window-dressing' hearings concerning a program which had already been decided upon and whose implementation was in progress. To do so, he said, would be "cynical in the extreme".

The Freshwater Institute of the Department of Fisheries and Oceans subsequently conducted a ten-year program of research on SIL after impoundment and diversion. Their findings indicate that while some of the pre-project assessments accurately predicted the impacts on SIL, there were signicant impacts that were not officially anticipated.

Southern Indian Lake lies in Manitoba's permafrost area. While the surface of the ground here was covered in an insulating mat of dead vegetation, a few feet down, water is permanently frozen. If that insulating layer of vegetation is broken, or if the ice melts from underneath, the ground collapses.

Over the thousands of years of its existence, SIL had achieved stable shorelines. But the impoundment of water for diversion to the Nelson system flooded out these shorelines, creating a vicious cycle of water thawing the permafrost, followed by slumping of the banks into the lake, followed by more permafrost melting and so on. In some places, the shoreline receded as much as 50 metres per year. Recent studies estimate that it will be in the order of 80 years before 90 per cent of the lake's shorelines have stabilized.

The most immediate and visible effect of this cycle was a reduction in light penetration as the water became more and more turbid. It took several years for the most devastating consequence to become apparent and understood.

Prior to diversion, SIL was the largest producer of export-grade whitefish in Manitoba, with catches exceeding 450,000 tonnes annually. Whitefish catches declined markedly after impoundment, possibly because the fish population dispersed to more favourable areas of the lake which were less accessible to fishing. As well, high sediment loads may have affected the survival of whitefish eggs. The last nail in the fishery's coffin was the discovery of methyl mercury contamination in the fish at a level exceeding Canadian marketing limits and, in some cases, export limits.

Elemental mercury is commonly found in Canadian soils. In this form, the mercury is insoluble and therefore not of concern. But elemental mercury can react with

methane to create methylated or methyl mercury, a soluble and bioaccumulative toxin. Inadvertently, the conditions for this transformation had been created in SIL.

With each slumping of the shoreline, the vegetation mats that once covered the permafrost fell into the lake where they began to decompose, using oxygen in the process. But during the winter, ice prevents oxygen replenishment and, as a consequence, the available oxygen was used up. The anerobic decomposition *that followed released methane as a byproduct. The methane combined with elemental mercury, now present in large quantities because of the same shoreline slumping, and methyl mercury entered the food chain. (SIL was the first demonstration of this phenomenon, but it has been shown to occur in the early years of most impoundments until shorelines stablilize. It will be decades before SIL's shorelines stabilize and, hence, decades before methyl mercury contamination ends.)*

Methyl mercury contamination forced the closure of the commercial fishery, disrupting the lives of SIL's predominantly native population, and depriving them of their livelihood. And if this was not enough, the natives were advised not to eat fish from the lake—their traditional staple.

When the diversion was licensed in 1972, neither the provincial government nor Manitoba Hydro had developed a plan to compensate those who might be negatively affected, nor were those who might have been affected fully informed of what would happen to their communities. In 1973, five native communities in northern Manitoba attempted to obtain a court injunction restraining Manitoba Hydro from proceeding with the diversion. When this failed, they formed a legal corporation, the Northern Flood Committee, and began negotiations with the province to obtain compensation for the damage to native communities. No progress was made until 1976, when a mediator was appointed to arbitrate the dispute. The resulting compact, the Northern Flood Agreement, *called for the replacement of flooded reserve land with Crown land and the payment of $89.2 million in compensation by the federal and provincial governments and Manitoba Hydro for losses in income from trapping and fishing.*

During the next seven years, Manitoba Hydro invested an additional $38.6 million, most of which was spent on mitigating the physical damage to SIL. $4.5 million of this amount, however, was allocated to keep the SIL community (which had been excluded from the Northern Flood Agreement) working in traditional jobs and to create a new native village. The mercury problem, which showed up several years after lake levels had been raised, virtually eliminated the sale of fish, and Manitoba Hydro and the provincial government made a final payment of $6 million to the natives for all future damages due to loss of livelihood. In total, the cost of social impacts at SIL exceeded $47 million. More recent estimates place this figure much higher.

On the other hand, the total investment in hydro development along the Nelson, initially estimated to be $663 million in 1970, topped the $1.35 billion mark by

1978, and costs have continued to escalate. The venture, however, has proven to be profitable, far exceeding the dollar value of the calculable social and environmental costs. In 1990, Manitoba Hydro's gross sales totaled $664 million, yielding $24 million in net income. Projections to the year 2000 anticipate total annual revenues of $1.4 billion. But this type of cost/benefit analysis tends to understate the environmental costs, not all of which can be easily assigned a dollar value.

When the Churchill diversion was initially recommended, it was to satisfy a growing domestic demand in the province of Manitoba, and energy export was seen as a way of increasing the profitability of hydro development. In hindsight, consumption of power in Manitoba has fallen short of expectations, and the province has exported electricity in order to recover its costs. Throughout the 1980s, export sales averaged about $100 million a year, a figure expected to rise to $320 million annually by the year 2000. When the $1.73 billion generating station at Limestone begins producing electricity in 1992, 500 megawatts will be sold to the Northern States Power Corporation of Minneapolis. And if the $5.5 billion, 1,390-megawatt station at Conawapa and its accompanying power lines are constructed, the Province of Ontario is committed to purchase 1,000 megawatts of power for $13.5 billion over a period of 20 years.

Table 3: Summary of Power Plant Capacity on the Lower Nelson

Plant	Capacity (in MW)	Date Completed
Kelsey	224	1961
Grande Rapids	472	1965
Jenpeg	168	1977
Kettle Rapids*	1,272	1978
Long Spruce*	980	1978
Limestone*	1,280	1992
Conawapa*	1,390	under consideration

**stations utilizing combined Churchill-Nelson flows*

Source: R. Newbury & G. Malaher, *The Destruction of Manitoba's Last Great River*, Canadian Nature Federation, Special Publication #2, 1973

The James Bay Project

In 1971, the Government of Québec announced its decision to develop the hydroelectric potential of the "remote and sparsely-settled" river basins draining into James Bay. Central to the plan was the diversion of some 1,700 m^3/s of water from neighbouring basins into the La Grande River, approximately 1,000 kilometres north of Montreal. The entire complex of eight dams, 198 dykes and five reservoirs would generate over 10,000 MW of electricity during the first phase of the project.

By any standards, the project, as conceived, is massive. It will alter the flow of nineteen rivers which drain an area the size of France. It will create dozens of reservoirs and require the construction of 20 powerhouses and 12 sets of transmission lines (See Table 4). It will also cause environmental and social disruption on an unprecedented scale, threatening habitat for migratory birds, caribou, beluga whales, freshwater seals and other wildlife and destroying traditional hunting and trapping grounds of Québec's 10,000 Cree and Inuit.

Table 4: The James Bay Project

La Grande, Phase One—Completed in 1985 after 12 years and a cost of $16 billion,it includes three reservoirs and powerhouses on the La Grande River (LG2, LG3 and LG4) with a combined production of 10,282 megawatts.

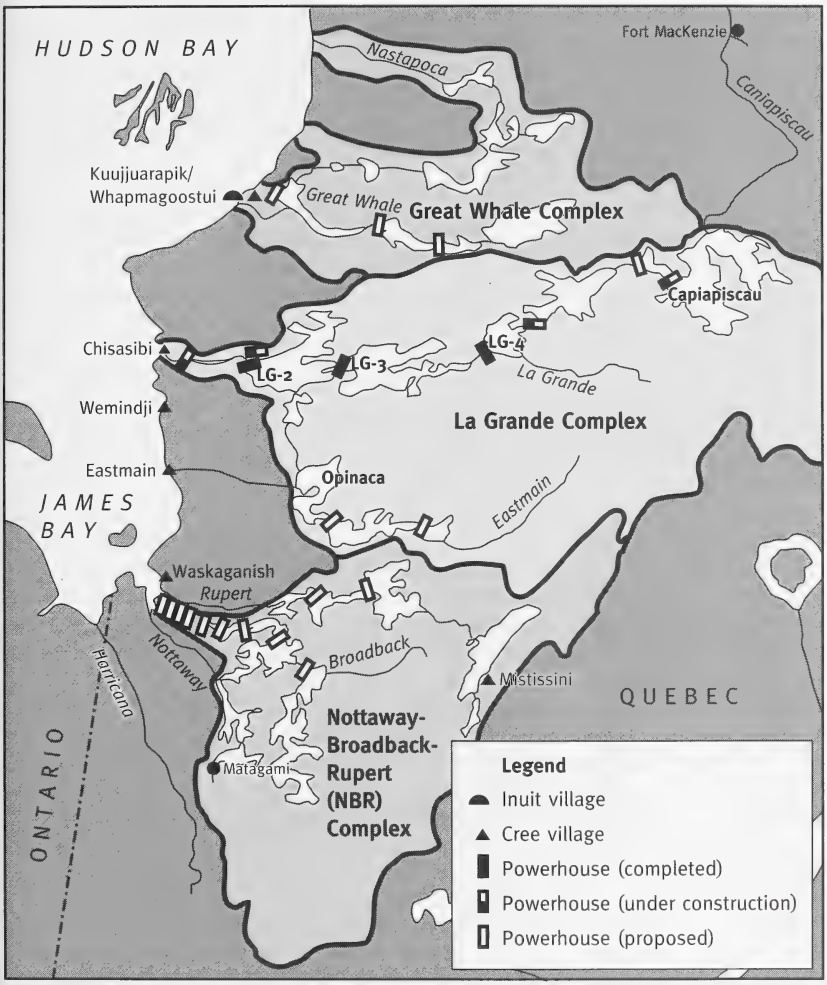
La Grande, Phase Two—Scheduled to be in operation by 1996. Includes LG1 and five more powerhouses on rivers diverted in Phase One.

Great Whale— Includes three power stations with a total capacity of 2,890 megawatts and the diversion of two other rivers.

NBR Project—Diversion of the Nottaway and Rupert Rivers into the Broadback River and construction of up to eight powerhouses. Targeted for completion by 2004, the Project is intended to generate 8,700 megawatts.

Most of the damage to the environment occurs when rivers are dammed or diverted. During Phase One, for example, 90 per cent of the Eastmain River's flows were diverted into the La Grande, eliminating fish spawning habitat and leaving much of the riverbed exposed to erosion. Just the opposite occurs in rivers that carry diverted water. Their flows are greatly increased, reducing shoreline habitat for ducks and other aquatic life. When dams are built, the reservoirs behind them flood river valleys, submerging vast areas of forests. Shorelines then become a tangled, inaccessible mess as trees and shrubs die and rot.

Normally, rivers run highest during the spring and are lowest in winter. The James Bay development will reverse this natural pattern. One result will be a change in water salinity in James Bay and Hudson Bay. That could, in turn, wreak havoc on



Source: *Electric Rivers*, Sean McCutcheon, Black Rose Books, 1991.

Figure 20: *The James Bay Project–One of the largest, and most controversial, hydroelectric developments in the world, the $6.2 billion James Bay Project, if completed, will generate 28,000 MW of power, or nearly ten per cent of the continental supply.*

fish and mammals that require specific types of food and water conditions. Coastal marshes and tidal flats, for example, are rich feeding grounds for migratory birds, which feed primarily on a small clam that lives in the mud. Millions of birds would starve if these clams could not survive changes in water salinity and temperature. Beluga whales winter in ice-free waters in James Bay, and would be at risk if altered river flows affect ice patterns in the Bay.

As in Manitoba, the decision to proceed with development, at least in principle, was made without prior assessment of environmental impacts. A joint federal-provincial task force, while having no input into the decision, did conclude that the La Grande site was less environmentally objectionable than a second site that was considered, because native communities were more widely dispersed and resettlement would not be required. Other environmental impact studies, however, concluded that native land use was essential to their well-being, a fact not appreciated by the task force. These later studies became important evidence in court action taken by the natives of the region to halt construction of the project until outstanding issues of property rights and compensation from damages to traditional land and water use were settled.

Prior to the decision, natives had not been consulted, nor informed that their aboriginal lands would be threatened. Although their court action was unsuccessful, it did lead to a settlement of land claims. In 1975, the James Bay Northern Agreement *was signed by the Cree and Inuit of northern Québec, the governments of Québec and Canada, and the crown corporations (Hydro-Québec and the James Bay Energy Corporation) involved in the development. This agreement, in addition to recognizing aboriginal land rights, contained provisions for improvements in housing, sanitation and health services, a detailed environmental assessment, environmental mitigation and compensation of $225 million to be paid out over a twenty-year period. This cash settlement amounts to roughly $1,000 per year for each of the 11,000 natives covered by the Agreement.*

While the James Bay Northern Agreement has provided a measure of relief for the Cree and Inuit, it has not truly compensated native villages for their loss of livelihood and for the afflictions of modern society that have come with development. Chisasibi, near the mouth of the La Grande River, has no economic base other than trapping and fishing to support its growing population. Despite the thousands of jobs created by the project, only five residents work for Hydro-Québec. Half the town is unemployed, and the people suffer from alarming rates of alcohol abuse, teenage pregnancy, divorce and suicide.

Perhaps the single most devastating effect of the project on Chisasibi has been mercury contamination of the fish, caused by the same processes that occurred in Southern Indian Lake. Traditionally, fishing provided not only employment and self-esteem but a dietary source of protein for native people. In 1984, two of every three villagers living in Chisasibi had unsafe levels of mercury in their bodies, and

today, no fish caught in the main La Grande reservoir and the river downstream may be eaten.

At first, Hydro-Québec estimated that high mercury levels in fish would last up to six years. It now says that mercury levels will likely remain high for ten to 20 years. The problem can be reduced by clearing areas of vegetation before they are flooded. However, due to the expense and difficulty of this operation, the utility is only clearing areas near power stations and around stream inlets where fish spawn.

Kuujjuarapik lies 200 kilometres north of Chisasibi where the Great Whale River flows into Hudson Bay. It is here that Hydro-Québec plans to build the next phase of the James Bay project. Kuujjuarapik, which was once accessible only by canoe or dogsled, and more recently by plane, will be linked to the south by a paved highway. While Hydro-Québec contends that provision for this phase was made in the 1975 Agreement, the Cree and Inuit of Kuujjuarapik are in disagreement. They have seen the effect of the project on the environment and communities like Chisasibi, and they want it stopped, or at least delayed until they can control it in a way that does not threaten their survival. Their experience with the first phase of the Project has thrust them into the world of international public relations, and they have learned how to play the media exceedingly well, to the point of travelling into New York City by canoe in an effort to persuade Americans not to buy electricity from Québec. It was front-page news in Canada and in New York, but the project was already becoming entangled in straight economics.

The construction of La Grande, Phase I, originally estimated at $2 billion, will cost nearly $15 billion, including transmission tie-ins to Ontario, New Brunswick and the northeastern United States. Thus, the average cost per kilowatt is about $1,500, one-and-a-half times the yearly compensation to each native. It is now estimated that the approximately 12,000 MW of northern Québec power that could be produced for export is worth $25 billion (in 1984 Canadian dollars). In Premier Bourassa's opinion, this 'cheap' power will save New England consumers some $3.5 billion in power costs over the next fifteen years, as well as generating substantial revenue for the Province of Québec.

The James Bay Project was originally intended to meet Québec's growing demands for electricity well into the next century. It soon became evident, however, that there were markets beyond the province's border, thanks largely to the decision by OPEC (the Organization of Petroleum Exporting Countries) to greatly increase the price of oil. In response, Québec has revised its timetable for the development of the remaining portions of the project—Great Whale and NBR—so that it can produce as much electricity as possible. But having surplus electricity is not the same as having large reserves of oil, coal or gas, and a number of conditions must be met before hydroelectric power can be delivered to customers in another province or country.

Hydroelectric power production is based on the kinetic energy of falling water. All hydro installations impound a certain amount of water to create sufficient head *(the vertical distance that water falls) to drive the turbines. The turbines then spin a generator to produce electricity.* Run-of-river *plants are built where the volume of flow in the river is sufficient and the river channel steep enough to produce the required head. Other plants depend on dams and reservoirs to store water and create head. Hydro facilities are always constructed with spillways so that water can be passed downstream when electricity is not being produced. Spillways also protect reservoirs from overfilling. In practice, hydro operators do not like to open their spillways, because water flowing past cannot be used to generate electricity.*

One of the key considerations in designing a hydro facility is the ability to meet peak demands. The export of power to utilities in the New England states and New York does not compromise Hydro-Québec's ability to meet domestic demands because of the difference in climate. Quebecers need most of their power in the winter to heat their homes, whereas urban residents of the northeastern U.S. use large amounts of electricity to run air conditioners during the summer. This means that Hydro-Québec can produce a constant flow of energy year-round. Hydro-Québec must also ensure that its power frequency is synchronized with those of other utilities connected to the same power grid. Any fluctuations can collapse the grid, causing massive blackouts.

Perhaps more important to Hydro-Québec is the assurance that its power will be used. Utilities like to have firm contracts that guarantee long-term purchases (say, 20 years) at a specified price. Hydro-Québec has been able to obtain firm contracts by selling electricity to U.S. power companies at attractive rates. These rates allow the companies to keep their own charges competitive and delay or even avoid constructing new power plants to meet increasing demands.

Some critics have argued that Hydro-Québec vastly overestimated the demand for electricity in the province and is trying to reduce its debt by selling power to the U.S at discounted prices. They point out that other utilities in the U.S. and Canada are now encouraging energy conservation, and that the additional phases of the James Bay Project would be unnecessary if people in Quebec and the northeastern U.S. were persuaded to reduce their consumption. This criticism may be justified.

Consolidated Edison, a New York utility, was planning to pay $6.5 billion to add 482 megawatts of Québec power to its grid. But the utility found that, by investing $4.1 billion in conservation measures, it could reduce its energy requirement by 2,425 megawatts. Faced with these savings, Con Ed opted for conservation rather than signing a long-term agreement with Québec. It was a major blow to the project, but the province has vowed it will still go ahead with construction.

Energy conservation initiatives could also work in Québec, where one-third of the province's houses have little or no insulation and office buildings in Montreal consume 30 per cent more energy than comparable buildings in the northeastern

United States. Experts predict that conservation programs could save up to half of the Great Whale's energy production or delay building the project for twenty years.

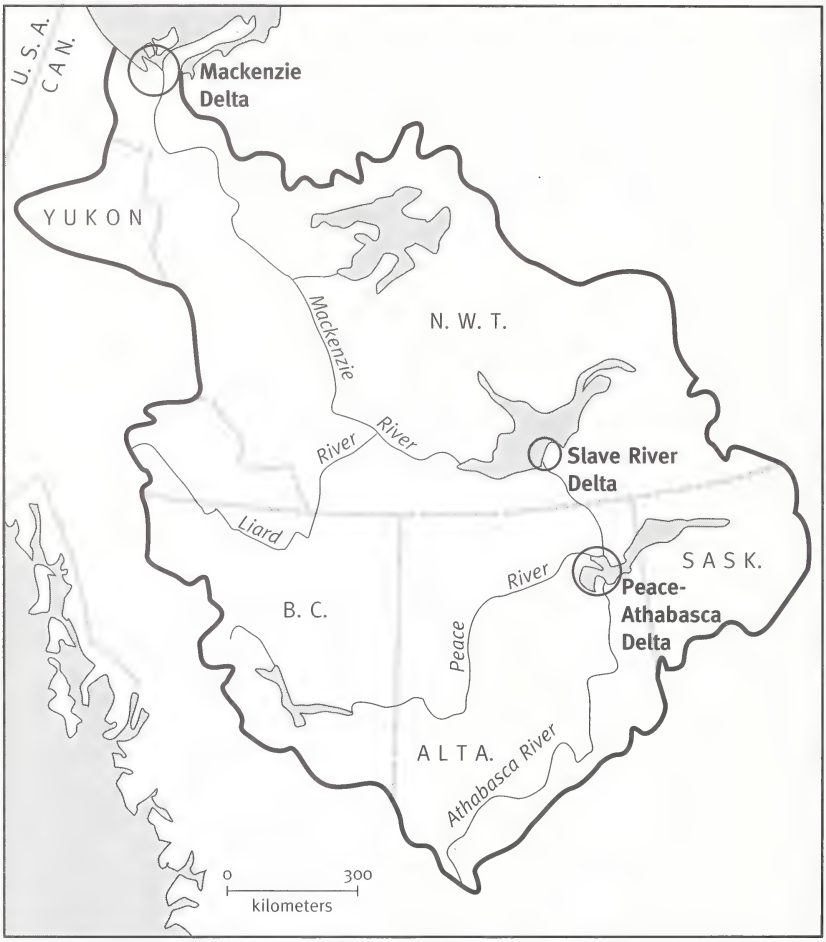
The James Bay and Churchill-Nelson River diversion projects illustrate the influence of provincial government policy on water resource development and an often rather cavalier approach to dealing with natives. In both instances, natives were not consulted about the projects nor informed of the damage that might occur to their traditional lands, and went to court in an attempt to halt construction. It can be argued that natives were compensated, at least to a degree, but the more important question, perhaps, is the impact of such megaprojects on traditional native lifestyles, which had to be abandoned in favor of more conventional or 'modern' employment.

There is little question that large-scale hydroelectric development is economically and politically attractive. The profits from domestic and foreign sales provide provincial governments with badly needed revenues at a time when important social programs are becoming increasingly difficult to finance. But even more than this, hydroelectric power development affords provincial politicians a degree of autonomy in managing their affairs. Several writers, for example, have linked the James Bay development to Québec nationalism and the province's desire for independence within a revised Confederation.

As with the Rafferty-Alameda project, James Bay falls within the jurisdiction of the federal government and is therefore subject to an environmental impact review. Hydro-Québec claims that environmental and social impacts are being minimized to the greatest extent possible, and has spent over $250 million on impact studies and remedial measures. The studies, however, were initiated after the James Bay Project was announced, prompting environmental groups to charge that the Québec government always assumed that the project would proceed and that it has only dealt with impacts after the fact.

Native opposition to the Great Whale development resulted in the call for a full-scale environmental review by the federal government, a move bitterly opposed by Québec which insists the project is entirely within its jurisdiction. When and if public hearings on the project take place (they have yet to be held in the province of Québec), they will probably centre on impacts to the environment and to native communities. But critics of the project suggest the debate should focus on a much broader issue: can humans limit their appetite for power so that megaprojects like James Bay will not need to be considered? Hydro-Québec assumes the answer is no. Environmentalists insist that it must be yes if the earth is to remain habitable. The James Bay Project, they say, will not just increase the damage. It will also

delay the push for energy conservation that is likely to come when there are no more alternatives.



Source: *A Primer on Freshwater*, Environment Canada, 1991

Figure 21: *The Mackenzie River Basin–An interprovincial river, the Mackenzie drains an area of some 1,300,000 km² in British Columbia, Alberta, Saskatchewan and the Northwest Territories. Pulp and paper, hydroelectric and mining developments all threaten the environment of the basin.*

The Mackenzie: Canada's Last Frontier

In the North, the name *Mackenzie* is synonomous with the majesty and beauty of unspoiled lands and rivers. The region was originally settled by ancestral North

American Indians migrating across the Bering Strait some 25,000 years ago. Today the Mackenzie River, named after the explorer John Mackenzie who discovered it while trying to find the elusive Northwest Passage, is still largely untouched by human development. It is this country's last great unspoiled river.

But the Mackenzie system is beset by similar development pressures to those put on southern rivers a century ago. The Northwest Territories alone contain an estimated 14 billion cubic feet of marketable timber. Between 1.4 and 1.6 million hectares of arable land have been identified along the floodplains of the Mackenzie, Slave, Liard and Peace Rivers. Conventional oil reserves have been estimated at 15 billion barrels and gas reserves at 90 trillion cubic feet. The Athabasca Tar Sands at Fort McMurray, Canada's largest single oil field, contain some 300 billion barrels of oil and an additional 300 trillion cubic feet of gas. The Mackenzie and Yukon Basins also hold a potential for hydropower development that exceeds all Canadian projects west of Ontario. The potential includes 14,000 MW on the Mackenzie itself and 10,000 MW on the Yukon. In all, some 50 sites have been identified in the Mackenzie Basin, including those on the Peace, Athabasca and Slave Rivers in B.C. and Alberta.

The Mackenzie River technically begins at the junction of the Liard and Slave Rivers at Fort Simpson, some 350 kilometres west of Yellowknife. But as we have seen, human activity upstream on a river can have major consequences downstream. And upstream from the Mackenzie's nominal beginning are three western provinces with dreams and aspirations for economic development.

In the early 1980s, the Alberta government seriously considered building a hydroelectric power plant on the Slave River, itself a transboundary watercourse formed by the joining of the Peace and Athabasca Rivers. The proposed facility would have flooded a portion of Wood Buffalo National Park. The federal and NWT governments were also concerned that river levels in the Mackenzie itself would be affected, with possible impacts to alluvial ecosystems in the river's delta, and changes in ice conditions causing flooding and impeding navigation. The project was shelved temporarily because Alberta's demand for electricity was less than projected, and could be met by thermalelectric plants, some of which were not producing at full capacity.

Then, in 1983, a massive oil spill on the Athabasca River near Fort McMurray, Alberta, fouled the water and killed thousands of fish. The spill came from Suncor's tar sand extraction operation, one of just two plants exploiting these immense reserves of oil. While the company was eventually prosecuted and fined, the spill sharpened fears over the impacts of future development. Full tar sand development at Fort McMurray has been estimated to require as much as ten per cent of the mean annual flow of the Athabasca River, prompting concern that reduced downstream flows would affect the Peace-Athabasca delta (already stressed by the development of the Bennett Dam in British Columbia) and would limit the river's capacity to dilute and assimilate future spills. Compounding these fears is the

large-scale expansion of the pulp and paper industry, being promoted in Alberta as an important additional step in economic diversification (see Study Four.)

Similar pressures exist on the Peace River. The $500 million Daishowa pulp and paper mill has recently been completed near Peace River, Alberta, and several sites have been proposed for hydroelectric power production. The Peace is the largest tributary of the Mackenzie, and flow regulation on the river could affect the timing of spring break-up, altering water temperature and sediment loads for hundreds of kilometres downstream.

The cumulative effect of development south of the 60th parallel has not gone unnoticed by Northerners. Their interests reflect a strong concern for the natural quality of their water resources, and they are clearly in a position to learn from mistakes made elsewhere. Their priority is not to protect what is left, but to maintain what they now have, and they have insisted on being granted a voice in joint federal-provincial discussions on water management in the Mackenzie Basin.

Discussion Questions

1. The current constitution divides authority for water management between federal and provincial governments. How might constitutional reform in Canada affect this balance, and are jurisdictional changes advisable?

2. Much of the debate surrounding water quality protection centres on what is considered to be an 'acceptable' level of pollution. What criteria would you suggest for setting water quality standards, and why?

3. Technology can be described as both a means of achieving a more promising future and a cause of social and environmental ills. Do you agree that technology is inherently good or evil? Why or why not?

4. Should the rights of a minority of citizens be protected even if that means renouncing the benefits of resource development for the majority?

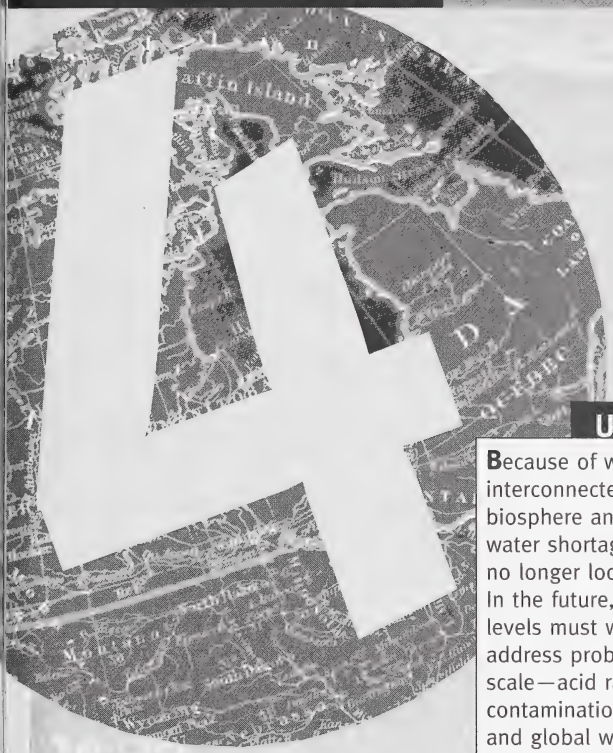
Recommended Readings

The Politics of Pollution
Doug Macdonald, McClelland & Stewart, 1991. *A comprehensive study of federal and provincial decision-making about domestic and international pollution over the past two decades.*

Electric Rivers
Sean McCutcheon, Black Rose Books, 1991. *An excellent reference on the James Bay Project. Includes a discussion of the natural and human history of the project, the financial and political interests behind it, and the impacts to native communities in northern Québec.*

Controlling Pollution From Canadian Pulp and Paper Manufacturers
William F. Sinclair, Environment Canada, 1990. *Reviews the history of pulp and paper mill regulation in Canada from a federal perspective.*

UNIT



Unit Focus

Because of water's interconnectedness with the biosphere and human activity, water shortages and pollution are no longer local but global concerns. In the future, governments at all levels must work together to address problems of international scale—acid rain, toxic contamination of water supplies and global warming. This will mean finding alternative ways to manage water which bring the demand more in line with the supply and afford an even greater degree of protection to the environment. But individuals can also help by changing their water-using behaviours and taking a more active role in defining sustainable environmental policies and practices.

Unit Objectives

At the conclusion of the unit, you should be able to:

1. contrast *acute* and *chronic* effects of toxic exposure
2. describe the methodology for setting *water quality guidelines* for drinking water
3. explain the concept of *externalities* and how it contributes to pollution
4. relate the price of water to patterns of consumption and *demand management*
5. apply the principles of *eco-nomics* to waste utilization
6. predict the impact of global warming on water demand
7. describe the problems posed by transboundary pollution
8. assess the importance of personal lifestyle choices for achieving sustainable development.

Key Concepts

At the conclusion of the unit, you should understand that:

1. water quality guidelines for drinking water consider both the technology of detection and levels of risk to toxic exposure
2. water is considered a *free good* and its price rarely reflects its value
3. wastes are resources in their own right and can be reused or recycled
4. the costs of development should be anticipated, prevented, or paid for when they are incurred
5. as the limits of supply are reached, *demand management* will be key to ensuring the sustainability of water resources and ecosystems
6. environmental problems are global and thus require solutions which transcend the political, social and economic priorities of individual nations
7. our individual responsibility to The Living Flow requires a commitment to change those personal habits and societal practices that are unsustainable.

Hour Four Overview

As far as we know, humans are the only species able to conceptualize the future, and no account of human progress would be complete without recognition of the immense drive this faculty engenders. But set against that is a short-term focus and selfishness which narrows the sense of future to the most immediate gratification of wants and needs.

Not surprisingly, this dichotomy is most apparent in our economic system. Promising an ever-better future through unending growth, the system depends on ever-growing levels of immediate consumption. But both growth and consumption are 'subsidized' by offloading environmental costs—pollution, the depletion of soil nutrients, destruction of forests—on the future. It's a form of deficit financing more damaging than the fiscal type, for there is no means of forgiving these loans from our children, and bankruptcy is not just an inconvenience.

The final hour of *The Living Flow* looks to the future and some of the economic and environmental questions that must be dealt with if Canadian and global society are to be made sustainable (without which sustainable development is not possible). The essay **ZERO** examines issues posed by our dependence on toxic materials. As the evidence mounts that continued use of these contaminants can and does pose a threat even at extremely low levels, we must come to terms with 'nothing', that seemingly most absolute of concepts. **CHOICES** takes an 'eco-nomic' look at the future of Canada's water. In many areas, limits to the supply are already limiting growth and greater attention must be paid to matching demand with supply while preserving the ability of The Living Flow to sustain non-human life. And, finally, in **RESPONSIBILITY**, five Canadians speak of their efforts to change, their hopes and their fears for the future.

ZERO—Essay Description

"Throw a single grain of salt into an Olympic-size swimming pool, and try to find it two days later. If you do, congratulations. You've discovered a concentration of about one part per trillion. If you don't, congratulations just the same. You've discovered zero."

Most people live in a world of absolutes, in which almost-nothing seems as absolute as nothing. But our technological ability to peer down the microscope and detect toxic chemicals at ever-lower levels—now at parts per quadrillion (that's a million billion) for PCBs—has made 'zero' nothing more than the point we just can't see beyond. Yet. But lagging far behind is our ability to determine what implications these *trace* levels have for human and environmental health. And fear grows in that gap—fear of one's drinking water, food and air.

Drinking water quality *guidelines* or *objectives* (the term varies in different jurisdictions) establish concentrations of contaminants thought to represent no risk (for toxic materials that have *acute* or short-term effects) or an 'acceptable' level of risk (for toxins thought to cause *chronic*, long-term health effects such as cancer). That acceptable level is generally a one-in-a-million-lifetime risk: in a city of three million people, over their lifetimes just three would end up with a chronic health effect from that concentration of a particular toxin in their drinking water.

However, these guidelines do come with a caveat. They largely deal with exposures to single toxins and, in their determination, there is a great deal of scientific uncertainty which is overcome by applying large safety margins. However, there is scientific and public controversy about whether these safety margins provide adequate protection against the possible combined effects of large numbers of toxic materials.

Officially, the answer is no, at least for those toxics persistent in the environment and bioaccumulative. In the Great Lakes, Canada and the U.S. have agreed to aim for *zero discharge* of these materials. In practise, zero has been defined by technology—either *undetectable*, or that level which can be achieved by *BATEA* (best available technology, economically achieveable).

However, essentially the same caveat as above must be applied—the discharge from any single source may present a negligible risk but thousands of sources, even at undetectable or best achieveable levels, may still add up to a threat. An increasing number of people argue that the only way zero discharge can be meaningfully achieved is through zero use, and they are calling for the *sunsetting* of specific chemicals, especially the organochlorines. Such sunsetting has rarely been used but the momentum for it is increasing. Ultimately, zero is as much a matter of choice as of technology.

CHOICES—Essay Description

"And just as water reflects its surrounding landscape, the choices we face in the ways we use and manage water reflect those larger changes—which go to the very roots of our economy, our lifestyle and our thinking."

In traditional economics, price is determined by the law of supply and demand. But water breaks that law—habitually. As a traditional economist would say, it's a *free good.*

For example, even when municipalities charge for water, consumers are merely paying for the costs of treating and delivering it to their taps. And even that is subsidized by taxes, an economic subsidy heaped on top of an 'environmental subsidy'—the water itself, which is free.

In fact, given the environmental subsidies we allow ourselves—free water, undervalued resources like trees, and pollution—our prosperity is little more than a bottom-line illusion. That illusion is shattered as we see the real costs finally accounted for: an estimated $20 billion to clean up industrial lands; perhaps as much as $100 billion to restore the Great Lakes. And the bills are climbing every minute of every day.

In an *eco-nomic* or full cost accounting system, the costs of pollution would be paid at, and by, its source. The idea is known as '*polluter pay*', but it's not a punitive measure. Forcing business to *internalize* rather than *externalize* these costs leads to more efficient processes that prevent pollution rather than controlling it after the fact. The challenge for governments is to create incentives that will put an end to this part of the bottom-line illusion.

Historically, governments have taken a *supply management* approach to water. As demand grows, the supply is increased. But supply management only works as long as *the myth of superabundance* holds true. It's already ended in Ontario's Regional Municipality of Waterloo where *demand management* is needed as the community outgrows its water supply. The stakes are high. Waterloo's supply options, and therefore its future growth, are limited by the growth of neighbouring communities and the Great Lakes region generally. The ultimate supply management option—massive diversions from Canada's north—is generally considered economically, environmentally and politically unacceptable. But the 'imperative of growth' seems to lead there unless all accept that there, unless all accept that development must respect some limits if development must respect if it is to be sustainable.

(The essay ends at this point for viewers of a broadcast of *The Living Flow*. For learners using video tapes, the essay takes a 'commercial break' (you may too), then continues.)

While there are limits to growth, there are few limits to opportunity. Water-efficient toilets, pollution prevention technologies, alternative energy and transportation systems will all contribute to a different kind of development; one turned inward, aimed at making the human enterprise fit within the 'business of the earth'—and that business is life.

In the Fraser Delta, preserves—the traditional means of habitat protection—are being augmented with *habitat compensation* and *banking*. Both are methods of paying the full costs of development *now*, and small examples of how, in the future, the price of progress will become the price of life.

We Canadians have both the opportunity and the obligation to create a sustainable society. But, to achieve it, we must change not just the externals of our economy but the internal 'landscape' of our thinking, and our myths as well.

RESPONSIBILITY—Essay Description

"We have seen The Enemy. and The Enemy is Us."

Beginning in the late 1980s, large numbers of Canadians began to rank the environment as one as the most important issues facing the country. This concern was coupled with a growing recognition that the problems were not 'out there' but in their own homes or parked in the garage. By no means a new analysis (a rejection of excessive consumption and waste has been a central element of environmental thought since the 1960s), this perception gained immense power as millions of Canadians recognized that responsibility begins at home.

But for many people the next step—taking action—has not proven easy. Where do you start? How fast do you go? And how far? Pollution, waste and environmental degradation are integrally woven into the lifestyle Canadians have striven to achieve. While the heart may be persuaded that this is the case, the mind rebels, finding all the reasons in the world (I don't know how. I can't afford it. I can't live without my _____. What does it matter what I do? I'm just one person!) to let another day slip by without change—or to embrace the easiest changes and let it go at that, ignoring the gnawing thought that we remain part of the problem. In our personal lives, we face the same quandaries that governments and business have often failed to surmount.

But any change taken with thought and courage feeds the next, and ripples outward. Recycling, once practiced by only a handful of people, is now practically *de rigeur* in communities across the country. Consumer demand for organically-grown fruits and vegetables allows a growing number of producers to move away from their chemical dependence. And shoppers seeking non-chlorine-bleached paper products cause manufacturers to reconsider their production processes, lessening the contamination of air and waterways with organochlorines. Each of us has power to the degree that we are willing to risk change in our lives. Each of us has the ability to press governments and business toward responsibility.

Realistically, however, these are no more than first steps. Like it or not, we are embarked upon a journey that must include a basic reassessment of the lifestyle we Canadians take so much for granted. For the first time in human history, that mythical place we call 'away' is no longer there. Trace the origins and consequences of the products we consume every day and it's clear that our personal environmental impact is simultaneously local, regional, national, continental and global. Our individual fate is inextricably linked with the whole of our species, with all other life and with this miracle we call both Earth and home. That link is The Living Flow—may it always be with us, may we learn to live within its grace, and may we learn to sustain it so it can sustain us. Responsibility starts at home and has no end.

Study Eight: Continental Pressures on the Resource

Up to this point, we have described water issues which are largely related to the Canadian scene. Even though we have been blessed with abundant water sources, we can ill afford to be complacent. Water's mobility connects us particularly with the United States (in ways we do not always like) and generally with the world beyond. The obvious and disturbing acidification of Canadian lakes and forests is in part due to transboundary emissions from U.S.-based fossil-fuel-burning power plants. Toxic substances leached from landfill sites south of the border contaminate the Great Lakes. Nor can we ignore the political, social and environmental ramifications of sharing our resources with a country having ten times the population but a water supply which parallels our own. From time to time, Americans have looked northward to Canada's water wealth with envy. Greenhouse-effect-induced climate shifts may increase pressures for water export. At issue is not just our future consumptive need, but the integrity of a resource many Canadians consider part of their heritage.

The Great Lakes

The Great Lakes are a truly magnificent resource. The system contains some 240 trillion litres of fresh water, 20 per cent of the world's supply and over 90 per cent of the U.S. supply. Collectively, the five lakes and their connecting channels have a surface area of more than 246,000 km^2 and a drainage area of well over one 100 million km^2. As both an international border and a shared resource, the system extends over 3,860 km from east to west. Thirty-seven million people reside within the Great Lakes Basin—20 per cent of the entire U.S. population and 60 per cent of the Canadian population. Approximately 150 billion litres of water from the lakes are withdrawn daily to serve the basin's residents, and one-fifth of U.S. and half of Canadian manufacturing is located here. Over a billion metric tonnes of cargo have passed through the St. Lawrence Seaway since 1954, and water-based recreation and tourism in the region generates between $8 and $12 billion annually.

Looking back, it is easy to see why the Great Lakes were a magnet for settlement. Initially, these interconnected waterways afforded fur traders a route to the continent's interior. Abundant rainfall and rich soils surrounding the lakes encouraged agricultural development. But more than anything else, the great shipping corridor from the Atlantic to the western tip of Lake Superior made this region the industrial heartland for both the U.S. and Canada. With the opening of the Welland Canal in 1827, and later the St. Lawrence Seaway, ocean-going freighters could transport iron ore, coal, minerals, petrochemicals and manufactured products through the Great Lakes region and beyond. Easy access to raw materials and the availability of cheap hydroelectric power spurred industrial development, leading to the growth of Canada's 'Chemical Valley' along the St.

Clair River at Sarnia, Ontario. The American equivalent is the Niagara River where at least 89 industries have located.

Figure 22: *The Great Lakes–The explorer Samuel de Champlain called them 'sweetwater seas'. Despite their area and immense volume, some estimates show consumptive demand by the region's 37-million-plus population will overtake the Lakes' renewable supply within 50 years.*

Despite their enormous importance and value to the economies of both countries, the Great Lakes have been badly treated. The Atlantic salmon which crowded the tributaries of Lake Ontario had all but vanished by 1898, victims of settlement pressures, their spawning beds destroyed by land clearing and their migration routes blocked by sawmills and gristmills. The decline in water quality was already noticeable around 1900, but not until mid-century was pollution serious enough to create serious public concern. Beaches on Lakes Erie and Ontario were routinely closed due to sewage contamination, and commercial fish like the whitefish and lake trout were replaced by suckers and bottom feeders. Lake Erie, the shallowest of the Great Lakes, became increasingly eutrophic. During the late 1960s, approximately 62,000 kilograms of this nutrient entered the lake every day—72 per cent of which came from municipal wastewaters, 17 per cent from rural runoff, seven per cent from urban runoff and four per cent from industrial wastes. In municipal wastes, 66 per cent came from phosphorus-based detergents.

It was the *International Joint Commission* which initiated a clean-up of the Great Lakes. As early as 1918, the Commission noted that connecting channels of the lakes (the Niagara, St. Clair and Detroit Rivers) were "unsightly and absolutely

unfit for domestic purposes". In 1951, the IJC commented that bacterial contamination from urban sources had tripled during the last four decades and that industrial discharges were now a major problem. By the late 1960s, urgent action was needed to reverse eutrophication, and so upgrading treatment plants and controlling phosphorus became the primary goals of the 1972 *Great Lakes Water Quality Agreement* between the United States and Canada. Since the signing of the Agreement, the two countries have spent nearly $10 billion to construct and upgrade municipal wastewater treatment plants in the Great Lakes Basin. As well, programs were implemented to limit the phosphorus content of laundry detergents. The effort has paid off: total phosphorus loadings in Lakes Erie and Ontario have decreased by 83 and 81 per cent respectively and both have shown improvements in water quality. However, the battle against eutrophication is not yet over, and additional measures are still required to control non-point sources of phosphorus and nitrogen, thought to come mainly from chemical fertilizers and gaseous emissions.

This bilateral action to control nutrients as been considered one of the most significant international success stories in water quality management. But a new problem has arisen to tax the resources of both countries: the presence of toxic substances in the Great Lakes. The Royal Society of Canada and the U.S. National Research Council, in a joint 1984 report, stated that people living around the Great Lakes were probably exposed to more toxic chemicals through their food and drinking water than any other population in North America. And a recent survey by Health and Welfare Canada found Canadians ranked drinking water quality as their second-greatest health concern.

In 1978, the Great Lakes Water Quality Agreement was amended to give much more emphasis to industrial pollutants, toxic substances and radioactive wastes, and to set water quality objectives for about 30 chemicals. A key aspect of the amended agreement was a commitment to the *virtual elimination* of industrial discharges of persistant toxics. This was to be achieved through *zero discharge*, a concept that raises a host of technological and social quandaries (see Study Nine). Today, zero discharge is increasingly accepted as a necessary strategy for sustainable development. But in the early eighties, the chemical industry was ill-prepared to accept the idea, and nowhere was its resistance stronger than along the Niagara and St. Clair Rivers, two of the principle sources of the chemicals in question.

The Niagara River accounts for 83 per cent of the tributary flow of Lake Ontario, the source of drinking water for more than five million Canadians. The 1984 report of the Niagara River Toxics Committee (NRTC), presented jointly by Ontario, New York State and the two federal governments, revealed that industrial and municipal facilities along the Niagara were responsible for discharging 1,400 kg of *priority pollutants* (a group of 129 toxins considered most dangerous by the U.S. Environmental Protection Agency. They include organochlorines like PCBs, dioxins and furans, polycyclic aromatic hydrocarbons, pesticides like Dieldrin and DDT, and

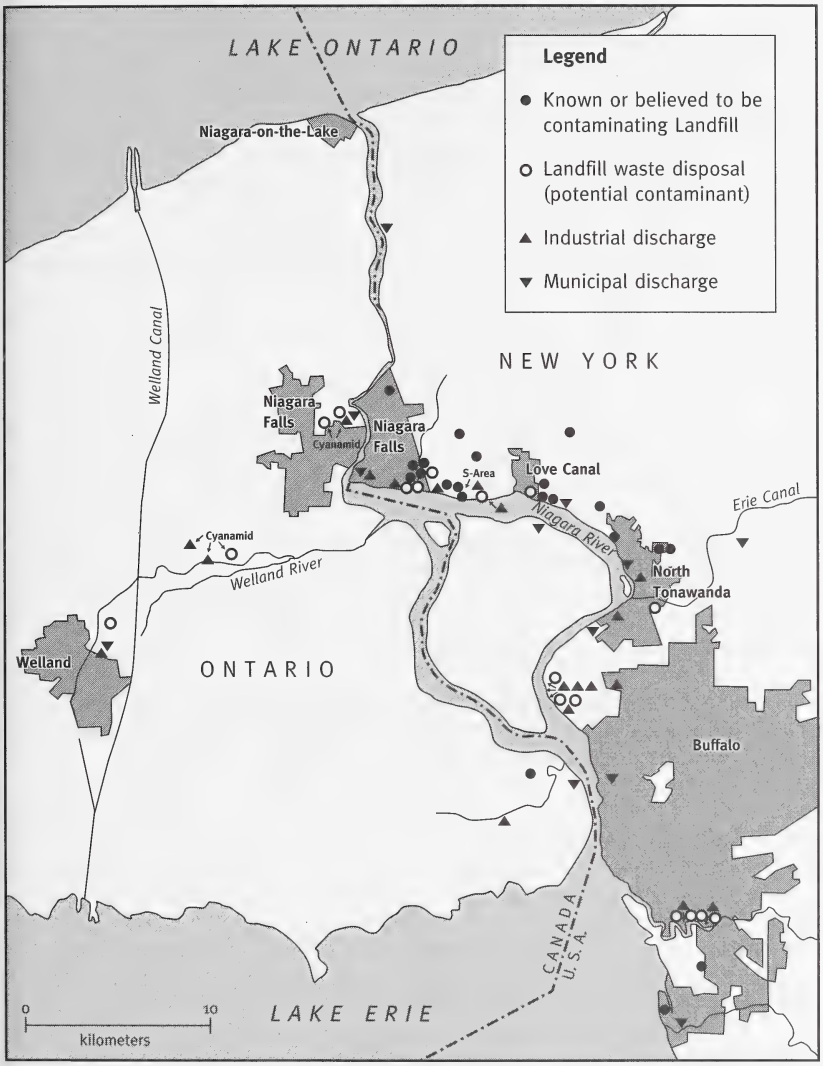


Figure 23: *NIAGARA POLLUTION SOURCES–The Niagara, considered one of North America's most polluted rivers, is lined by dozens of chemical industries attracted to the region by plentiful water, and by the cheap power provided by Niagara Falls since the turn of the century.*

heavy metals such as lead and mercury) into the river every day. The NRTC also identified a less obvious but equally important source of pollution—164 hazardous waste disposal sites along a four-and-one-half kilometre stretch of land in New York State adjoining the Niagara River. After studying the contents of these dumps, their proximity to the river, the composition of the land upon which they were built and the flow pattern of groundwater, NRTC officials concluded that 61 of the sites had had or would have an impact on Niagara River water quality.

While the need for clean-up was identified as urgent, the task of curbing pollution along the Niagara River has been hampered by the lack of effective regulation and a reluctance by polluters to take proper remedial action. A few examples:

• The Niagara Falls, N.Y., Sewage Treatment Plant received, in addition to municipal sewage, the wastewaters of 26 industries. The plant was not adequately designed to treat toxic wastes. Effluent samples revealed the presence of 34 priority pollutants in concentrations up to 75 mg/L. It took two years of public pressure and critical news coverage before the U.S. EPA invested $4.4 million to upgrade the plant, even though problems were likely known for some time.

• The Olin Corporation Plant in Niagara Falls, N.Y., was fined $70,000 for falsifying environmental reports which concealed the dumping of up to 13 kg of mercury per day into the Niagara River. Olin's discharges included at least 50 priority pollutants, yet its permit provided control for only mercury, pH, total suspended solids and BOD.

• Cyanamide Welland was prosecuted under Ontario's Environmental Protection Act for discharging ammonia into the Niagara River. Cyanamide was found guilty, but fined one dollar. In the presiding judge's opinion, this fine reflected the offence's severity.

• SCA Chemical Services of Lewiston, N.Y., has one of the two largest waste disposal sites in the U.S. Between 1972 and 1978, the company had accumulated 50 million litres of toxic wastes from 31 states, Canada, Puerto Rico and Taiwan. In 1978, SCA applied for a permit from the State of New York to discharge effluents from its toxic waste disposal plant into the Niagara River. Despite public protest, the permit was granted. Soon after, out of fear, Niagara-on-the-Lake began obtaining its drinking water from St. Catharines, Ontario.

• Hooker Chemical's Hyde Park site in Niagara Falls, N.Y., contains a number of chemicals, including mirex, benzene and approximately 900 kg of dioxin. After leachate from the site was found to be contaminating Bloody Run Creek, a tributary of the Niagara River, the EPA filed suit against the company. An out-of-court settlement required Hooker to line the site to prevent seepage and to pre-treat effluent sent to the Niagara Falls Sewage Treatment Plant. This action was far

less expensive than the total removal of contaminated wastes from the site suggested by environmental groups and officials of the Canadian Wildlife Service.

Sarnia's Chemical Valley includes petroleum refineries and petrochemical plants, most of which line the banks of the St. Clair River. These industries discharge a daily total of 1.7 billion litres of process, cooling and storm runoff into the river. Over the last twenty years, there has been a considerable reduction in the discharge of pollutants from improvements in treatment technology and recyling. Still, the river is subject to continued contamination by spills, waste disposal sites and agricultural pesticides, 70 per cent of which have been identified as potentially hazardous to the environment. As well as being a conduit for wastes, the St. Clair River supports an extensive sports fishery and is a source of drinking water for downstream communities on both sides of the border.

National attention was drawn to the St. Clair after Dow Chemical Canada Ltd. spilled 11,000 litres of perchloroethylene (a dry-cleaning fluid) into the river in August of 1985. The spill led to discovery, on the bottom of the river, of a black, tarry substance (quickly labeled the 'blob' in the media) which contained at least 18 hazardous chemicals including dioxins, furans and benzenes. Nor was this an isolated incident. Between 1972 and 1984, there were 275 spills reported in the Sarnia area, and in 58 per cent of the cases, some product reached either the St. Clair River or its tributaries.

Petroleum wastes may have other ways of getting into the river. Within three kilometres of the St. Clair are eleven waste disposal sites. Some, but not all, are monitored, and while most are located on top of clay deposits relatively impermeable to seepage, the potential for ground and surface water contamination remains. Immense quantities of wastes are produced in Sarnia, and some are applied to the soil, a practice known as *land farming*. Two companies, Shell and Esso, annually dispose of 18,500 cubic metres of oil wastes in this manner. Industrial wastes are also disposed of by *deep well injection*—a practise considered environmentally safe if the wells are sufficiently deep and the overlying rock strata prevent the entry of wastes into aquifers. From 1950 to 1976, eight million cubic metres were discharged under pressure into the ground surrounding the Detroit-St. Clair River region. The practise was discontinued when wastes began bubbling to the surface of the wells. Studies indicate the regions's bedrock is fractured and wastes may have entered groundwater or migrated laterally into the Detroit and St. Clair Rivers.

The Niagara and St. Clair Rivers are among the most polluted in North America. Their degradation is due not only to the continued discharges of industrial and municipal effluents, but to the long history of industrial development that has, until relatively recently, been unregulated. Disposal practises that are no longer acceptable have left chemical dumps—'toxic time bombs'—which have forced people from their homes (e.g. the Love Canal, 1978) and continue to threaten the drinking water of millions of people. In response, the U.S. has created a

'superfund' of $1.6 billion (raised from taxes on the production and importation of certain chemicals) to finance the clean-up of toxic waste dumps across the country—an amount that seems inadequate given that estimates for cleaning up the Niagara River sites alone range as high as one billion dollars.

These rivers are special cases because they are international waterways. No one level of government has the regulatory authority to set standards or prosecute offenders, nor has any been willing to allocate the necessary funds to solve the problem. While the Great Lakes Water Quality Agreements have been instrumental in reversing eutrophication, toxic contamination of the lakes is infinitely more complex and remediation will be considerably more expensive. The U.S. policy of regional equity (one region should not gain a competitive advantage over another from lax or unduly harsh environmental regulations) may further hamper bilateral attempts to reduce toxic discharges.

Acid Rain

Acid rain, or more technically *acid precipitation* (which includes rain, snow, sleet and hail) is usually defined as having an acidity below pH 5.6. The pH scale is used to measure soil or liquid acidity and ranges from 0 (maximum acidity) to 14 (maximum alkalinity). A value of 7, the pH of distilled water, is neutral. Because the scale is logarithmic, there is a ten-fold difference between one number and the next. Thus, the pH of vinegar (2.8) is ten times less acidic than lemon juice (pH 1.8), and ammonia (pH 11.9) is 170 times more alkaline than baking soda (pH 8.2).

Acid rain is primarily caused by emissions of sulphur and nitrogen oxides from coal-burning power plants, smelters and automotive exhaust. These oxides react with water vapour in the atmosphere to form sulphuric and nitric acids, and these fall to earth in precipitation, a process technically termed *wet deposition*. A second process, known as *dry deposition*, occurs when particles of sulphur and nitrogen oxides drop from the atmosphere and are converted to acids when they contact water on the surface.

Much of our concern about acid rain in Canada is directed at our eastern lakes and streams. In Nova Scotia, the prized Atlantic salmon have vanished from nine rivers having pH measurements of below 4.7, and eleven other rivers are threatened. Streams in eastern Newfoundland have pH values ranging from 5.3 to 6.1. While these levels are not yet critical, the province feels that further increases in acidic pollution may decrease salmon and trout productivity. In eastern Canada, more than 14,000 lakes are biologically dead from acid rain and 300,000 are considered vulnerable. Nor is the problem limited to the eastern part of the country. Acidification has been observed in all provinces west of Ontario. Precipitation with a pH as low as 4.6 has been reported in northern Saskatchewan, and rainfall in the lower mainland of British Columbia measures pH values as low as 4.5.

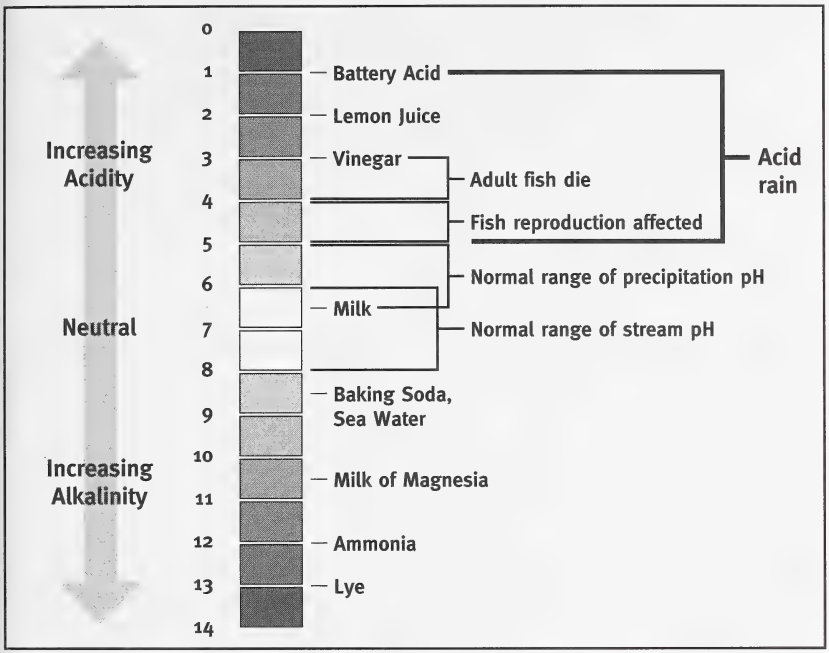


Figure 24: *The pH Scale–Each step on the scale is logarithmic so a pH of 3 is ten times more acidic than a pH of 4. Acid rain is considered to have a pH of 5.4 or lower.*

Acid rain poses a serious threat not only to aquatic habitats but to all sectors of the economy. The forest industry is this country's largest enterprise, employing about one million people and generating $12 billion annually. If acid rain reduces forest productivity, and many scientists suggest that it will, the costs to the Canadian economy will be substantial. In Québec, 52 per cent of the province's sugar maple stands already show signs of *dieback*, literally a slow death from the top down. Although there is still some question if acidification is the only factor involved, there is no doubt that acid rain is a major factor. Building materials and statues are seriously affected by acid deposition (causing an estimated $285 million a year in damages), and it has now been suggested that perhaps one-half of automobile corrosion in Canada is due to acid rain. Human health implications are not yet clear, but one study showed a correlation between increased hospital admissions from respiratory illness in southwestern Ontario and increased air pollution. Elevated levels of mercury in fish and potable water supplies, both attributable to acid rain, could also pose a threat to human health.

A visit to Sudbury, Ontario, in the early 1970s would have shocked the uninformed traveler. West of the city, the vegetation was lush and green, but to the east, bare rock and blackened stumps stretched to the horizon—a scene that came to be

called 'the moonscape'. It was a legacy from the very earliest days of the city's nickel and copper mines, when raw ore was dumped on the ground, piled over with wood and burned. Laden with poisonous heavy metals and sulphur, clouds of smoke drifted eastward, searing the vegetation in their path. Moving to smelters and smokestacks, the mines were able to control and reduce their heavy metal emissions, but local fallout of sulphur dioxide remained a concern. Believing that sulphur dioxide in the upper atmosphere was rendered harmless in a matter of days, the International Nickel Company (INCO) inaugurated its 381-metre-high 'superstack' in 1970 (a move that was followed by other large smelters in Ontario, Manitoba and Québec but without INCO's sheer scale).

However, the strategy was only locally successful. Even in the upper atmosphere, sulphur dioxide combines with water to form sulphuric acid, and the net effect of this 'dilution' technology was to cast pollution to the winds, allowing it to fall as acid rain hundreds, even thousands of kilometres to the east. These same prevailing winds carry acid emissions back and forth across the Canada-U.S. border. It is estimated that about four times as much sulphur enters this country from the U.S. than moves in the opposite direction, and that Americans are responsible for 50 per cent of sulphur-sourced acid rain here (the other half originates from emissions in Canada—see Table 9.1). Nitrates are thought to contribute up to 30 per cent of our acid rain problem, and Canadian authorities believe that a substantial portion of this comes from the United States.

Table 5: Sources of Sulphur Dioxide in Canada (tonnes/year)

Inco Ltd., Copper Cliff, Ontario	868,000
Noranda Mines Ltd., Noranda, Ontario	538,000
Inco Ltd., Thompson, Manitoba	359,000
Hudson Bay Mining & Smelting Ltd., Flin Flon, Manitoba	212,000
Ontario Hydro, Courtright, Ontario	160,000
Ontario Hydro, Walpole Township, Ontario	155,000
Algoma Steel Corporation Ltd., Wawa, Ontario	141,000
Falconbridge Nickel Mining Ltd., Falconbridge, Ontario	122,000
Suncor Inc. (Oilsands Division), Ft. McMurray, Alberta	93,000
Ontario Hydro, Lakeview Station, Mississauga, Ontario	91,000

Source: Environment Canada, Air Pollution Control Directorate, 1981

Lakes and streams in eastern Canada are particularly susceptible to acid rain because the rocks and soils of the Canadian Shield lack natural *buffering* or neutralizing capabilities. This fact has led to experiments in *lake liming*, where limestone, soda ash and potash (all alkaline substances) have been added to raise pH. Liming of lakes has been carried out in Sweden, New York State and Ontario with promising results. For instance, forty-five tonnes of powdered lime were

added to Nelson Lake, north of Sudbury, over a period of two years, and it now appears that a productive fishery that was almost eliminated can be re-established. But liming is an expensive procedure, and will not return a lake or stream to its natural state. Furthermore, many of the acidified lakes in eastern Canada are in remote areas, making liming impractical. Research at the Experimental Lakes Area (near Kenora, Ontario) has shown that there are naturally-occurring processes in lake sediments that can neutralize acidity, provided that inputs of acidity are held to a low enough level.

The same principle has been used to reclaim portions of Sudbury's moonscape. Scrambling up and over the blackened rock, thousands of people have spread crushed limestone. Within a few years, small shrubs and trees appear where before there was nothing but a heavy-metal-and-acidity-tolerant mutation of tufted hair grass. The program was mounted by the community and partially funded by the smelters. In its early years, restoration concentrated on the hills surrounding the city's highway entrances, and the casual visitor no longer sees the devastation. The plan is to restore all of the affected area. A proposal to leave a small area as a monument and warning to future generations has met with a cold shoulder from the smelter owners.

The long-range transport of acid emissions raises some fundamental issues about transboundary pollution. Canadian citizens appear to be much more aware of the acid rain problem than their American counterparts because the damage is more significant in this country and is probably more publicized. Between 1980 and 1984, the government of Canada allocated $41 million to fund research on acid rain, several times more on a per capita basis than spent by the United States during the same period. In 1984, Canada unilaterally implemented a program to reduce sulphur dioxide emissions to half of their 1980 levels (to 2.3 million tonnes per year or a maximum sulphuric deposition rate of 20 kg per hectare per year) and brought automobile emission standards in line with those in the U.S. Both Ontario and Québec have sought to reduce acid emissions in accordance with these federal guidelines. Cleaning up existing smelters to meet this target is estimated to cost more than $211 million, and employment of state-of-the-art abatement technologies in new facilities will cut profit margins of industries attempting to comply with more stringent environmental standards. The benefit, however, is reduction of the damage acid rain is causing to the environment, human health, and the economy.

The United States has been slower to make a similar commitment. While the two countries did sign a memorandum of understanding in 1980 to pursue a formal transboundary air pollution agreement, successive administrations delayed any meaningful progress toward an acid rain accord. Soon after the memorandum was endorsed, President Carter announced a program to convert over one hundred oil-fired power plants to coal. If implemented, this plan would have increased, rather than decreased, U.S. sulphur dioxide emissions. Although Carter realized that his

decision would harm U.S.-Canada relations, the goal of energy self-sufficiency was considered to be more important.

When Ronald Reagan assumed the presidency in 1981, his appointees in the Department of the Interior and the EPA disagreed with their Canadian counterparts over the extent and danger of acid rain, insisting that further research was necessary before control measures could be implemented. Two years later, a plan developed by William Rucklehaus, the new EPA administrator, to institute modest reductions in emissions was opposed by other cabinet members on the grounds that it would be too costly for American electric power utilities and ratepayers. Despite recommendations by the National Academy of Sciences that immediate action be taken to reduce acidic emissions, the Reagan administration refused to budge. Finally, after eleven years of U.S. inaction, President Bush and Prime Minister Mulroney signed the Acid Rain Accord in 1991. The agreement commits both nations to reduce sulphur dioxide emissions to half of the levels measured in the baseline year of 1980, the U.S to do so by the year 2000 and Canada by 1994 (a goal this country was already prepared to meet). Critics have argued, however, that the accord is little more than a handshake agreement and lacks enforcement and monitoring provisions. Moreover, they point to the fact that the 20 kilogram per hectare per year deposition rate enshrined by the accord is twice the level needed to allow highly acidified lakes in eastern Canada to recover. These lakes will continue to acidify, as will soils and forests, until action is taken to reduce emissions even further.

The issue of acid rain provides a good illustration of the complex interrelationships between water, pollutants, politics and the environment. Both countries face enormous environmental damage from this insidious type of pollution. Remediation of the problem is not a question of technology but of political will. Both countries will need to examine their domestic policies and legislation and decide whether the costs of still further reductions are politically and economically feasible.

Water Export

The American southwest is an arid region characterized by scanty precipitation and a relative scarcity of surface water. Portions of the region—southern California, Arizona and western New Mexico—are largely deserts. The High Plains area, which includes portions of New Mexico, Texas, Oklahoma, Kansas, Nebraska and Colorado, was originally grassland but is now farmed extensively. Like the western Canadian prairies, the land is fertile and can produce a variety of crops if irrigated.

In 1893, the population of the southwest was roughly 1.5 million people. Today, over 28 million live here and the region, which contains some of the fastest-growing metropolitan areas in the U.S., is home to one in fourteen Americans. The agricultural productivity of the southwest is also impressive. In 1977, crop values totaled $8.7 billion and livestock $7.9 billion, over 18 per cent of the nation's

total. Arid lands produced 66 per cent of the nation's cotton, 39 per cent of its barley and 21 per cent of its wheat. Such phenomenal growth has only been possible by overcoming the region's most fundamental deficiency, water. This has been accomplished in three ways: taking water out of the ground, damming the region's rivers, and transporting water from where it is abundant to where it is scarce.

The Ogallalla Aquifer, a huge underground reservoir estimated to contain 2,465 km^2 of water, underlies the High Plains. Some 70,000 wells now tap the aquifer, withdrawing nearly 17 billion cubic metres of water annually (about half of the total withdrawal use in all Canada in 1981) to irrigate six million hectares of farmland. A more accurate term to describe these withdrawals is *mining*, as far more water is being removed from the Ogallalla than is being replaced by recharge. This practice is not sustainable over the long term, so farmers are permitted a groundwater depletion allowance to reduce their taxes, in much the same way as oil companies. The situation is similar in the Santa Cruz Basin near Tucson, Arizona, where 680,000 m^3 of groundwater is overdrafted every year, mainly for agricultural purposes.

The major source of surface water for the southwest is the Colorado River. The river is fully apportioned among six states—Colorado, Utah, Wyoming, Arizona, Nevada and California—and is so heavily used that not much flow is left by the time it crosses the border into Mexico. By treaty, the U.S. must supply Mexico with 1.8 million dam^3 of the Colorado's annual flow. While the U.S. has had little problem with the quantitative aspect of the treaty, it has had to build a massive desalinization plant at the international border to remove salts from irrigation return flows (by 1973, the concentrations of these salts in the Colorado River had risen to 2,700 ppm. The Canadian guideline for total dissolved solids in raw drinking water supplies is 500 ppm; for irrigation, 500-3,500 ppm, depending on the crop).

The San Joachin Valley of southern California is an oasis in the desert, providing nearly five billion dollars worth of crops annually, including cotton, grapes, tomatoes, barley, alfalfa, sugar beets, apricots, walnuts and almonds. The valley is so productive because the soils are rich, the growing season is long, and the climate is similar to the Mediterranean. Of the valley's nearly two million hectares, 97 per cent are irrigated. Forty per cent of the San Joaquin Basin's water supply comes from aquifers that are being depleted by 18 million m^3 annually. Another 40 per cent comes from local streams. The remaining 20 per cent is imported from northern California, courtesy of the Central Valley Project, a $3.5 billion public works project transferring six million dam^3 of water to Los Angeles and the San Joaquin Valley each year.

Water makes the desert bloom, and more of it will be needed to keep pace with the growing cities and farmlands of the southwest. With this in mind, Arizona went to court to obtain what it considered its rightful share of the Colorado River.

Following a favourable Supreme Court Decision, the state then set out to finance the Central Arizona Project, a three-billion-dollar venture to divert water from the Colorado to Phoenix and Tucson. Now deprived of about ten per cent of its previous allocation, California sought to tap a greater amount of its northern supply by building a peripheral canal to link the Sacramento River with the Central Valley Aqueduct. The project was voted down by Californians, in part because further diversions of the Sacramento would have affected the fresh-salt water balance of its delta near San Francisco Bay.

The political and economic pressures for water in the American southwest are so pronounced that several observers of the North American scene have characterized the situation as a 'crisis'. Major problems require major solutions, and in this case, one proposed 'solution' is to divert the large and mainly 'unused' water supplies in Canada to the United States. In the past 30 years, there have been a number of schemes for continental diversions that, from an engineering standpoint, are technically feasible. One plan put forward by Thomas Kierans, a Canadian engineer, would dam James Bay and transfer 12 million dam^3 annually through the Great Lakes to the U.S. southwest and western Canada. Kierans insists that his scheme, the GRAND (Great Recycling And Northern Development) would merely 'recycle' water that otherwise would flow into the ocean. Other proponents of GRAND argue the cost, estimated at $100 billion, would be justifiable in light of the huge benefits to agricultural development (Québec Premier Robert Bourassa also favours the plan). Another, the NAWAPA (Northwest Water and Power Alliance) advocated by Ralph Parsons of Pasadena, California, would divert 135 million dam^3 of water from the Mackenzie and Yukon Rivers southward through the Rocky Mountain Trench at a cost of $120 billion. These and other 'pipe dreams' have never been seriously discussed by the Canadian and American governments because of their enormous capital costs and the irreversible ecological and social damage they would cause.

The question of cost is important because U.S. farmers often pay very little for water. For example, those who will benefit from the Central Arizona Project will pay $2/acre foot of water (about 1,233 m^3), although a study of the High Plains region indicated water users might pay as much as $75/acre foot. On the other hand, the cost of importing water to the High Plains could be as high as $1,000/acre foot. It may be argued that state and federal governments, because they have subsidized water projects in the southwest in the past, might be persuaded to finance continental diversion schemes. But voters in California and Texas (who rejected the $3.5 billion Texas Water Plan) appear unwilling to support massive spending for storage and diversion projects. More significant is a shift in priorities and approaches. Arizona has begun a program of retiring agricultural lands so that more important municipal needs can be adequately met, and now allows the buying and selling of water rights. Other states have followed suit and there are now businesspeople who specialize in arranging deals between buyers and sellers of water rights. Such transfers may well reduce water shortages. As well, western

governors now see more direct state involvement in small-scale projects and a greater emphasis on using existing supplies more efficiently.

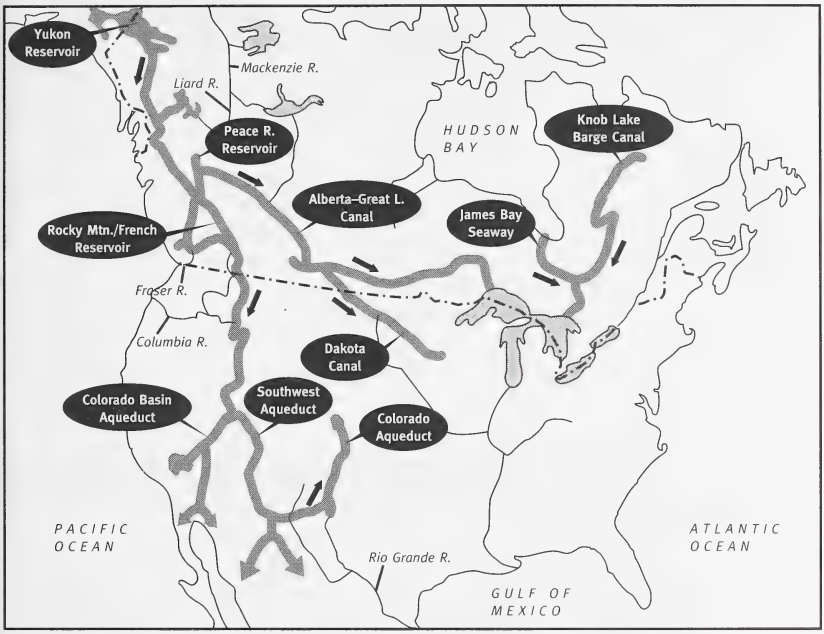


Figure 25: *The NAWAPA (North American Water and Power Alliance) Scheme–One of the several proposals for the massive diversion of Canadian waters to the American Southwest, the NAWAPA Scheme has attracted more controversy than serious consideration.*

Other events, however, may transform the pipe dreams of continental water transfers into concrete proposals. There is now strong evidence that our climate is gradually warming up. Since the 1800s, the concentration of carbon dioxide around the globe has increased by 80 per cent, and carbon dioxide concentrations in the atmosphere are now thought to be increasing at a steady rate of three to four per centper decade. Given our current rate of fossil-fuel consumption, concentrations of CO_2 will be almost double pre-industrial levels sometime around the middle of the next century.

Carbon dioxide, in concert with other gases, traps radiant energy from the earth's surface, similarly to a greenhouse (thus the term *greenhouse effect*). Consequently, the earth's average temperature is expected to rise. The effect of climate warming will not be uniform, however. In the Great Lakes region, winter temperatures are predicted to rise by three to four degrees, by six degrees in the high arctic, and by two-and-one-half to three degrees over the northern plains. Increased precipitation in central Canada and the prairies will be offset by increased evapo-transpiration

from crops and much greater evaporation from large waterbodies like the Great Lakes. On the other hand, wherever soils permit, northern Ontario and the southern portion of the Territories will be capable of growing the same kind of crops presently harvested several hundreds of kilometres south. In the present great plains region, including the 'breadbasket' of the U.S., more frequent and severe droughts are anticipated.

What climate change will portend for Canadian water resources is still very much a matter of debate, but if there are strong pressures for export, they could be at places where transfers are presently occurring. The Chicago Barge Canal, constructed in 1848 to keep Chicago's municipal sewage out of Lake Michigan, discharges 90 m^3/s of water from the Great Lakes into the Mississippi River. During the dry summer of 1988, the governors of states bordering the Mississippi asked that this diversion be increased to maintain flows for barge traffic along the river. The move was opposed not only by Canadian interests, but by governors of the Great Lakes states. Part of their opposition centred on the possible lowering of lake levels by increased diversions. A fifteen-centimetre drop would result in lost shipping revenues through the St. Lawrence Seaway of $20 million annually, and a flow reduction of 180 m^3/s would cost hydro producers in Ontario and Québec $175 million each year. Beyond that, for decades these 'rust belt' states have watched industry flee to the 'sun belt'. As shortages impede development in the southern and southwestern U.S., the governors believe Great Lakes water will be their ultimate ace, drawing industry back and assuring their own future.

The possibility of transboundary water transfers at the Chicago Barge Canal raises legal issues as well. Although Lake Michigan, by virtue of its connection to the Great Lakes system, is commonly thought of as a boundary water, it lies totally within the United States, and therefore is not technically governed by the Boundary Waters Treaty. The *Great Lakes Charter*, signed by the eight Great Lakes states and the provinces of Ontario and Québec in 1985, establishes mechanisms by which signatory parties would consult each other before a major diversion took place. The Charter, however, is a non-binding agreement and has no legal standing in either the U.S. or Canada.

Finally, there is the question of water and the *Canada-U.S. Free Trade Agreement*. Despite claims to the contrary by the Mulroney government, there are those who believe that water is part of the agreement by virtue of its inclusion under tariff heading 20.01, under the term "good" and under Agricultural Goods. The Free Trade Agreement with the United States also removes tariff barriers that might protect Canadian water from export to the United States. It is likely that additional agreements would have to be signed before continental water diversions took place, yet the Free Trade Agreement accords both countries "national treatment" which prevents either from using internal measures (e.g. taxes, charges, laws or regulations) to protect any of its products or resources.

The Canadian government has stated that its Federal Water Policy would prevent the export of water to the U.S., as would the provisions of the *Canadian Water Preservation Act*. While such policies and legislation have some meaning domestically, they do not change the Free Trade Agreement which could allow the United States to argue that the prohibition of water exports nullifies its national treatment rights under the Agreement. Clouding the question still further is the *North American Free Trade Agreement* between Canada, the United States and Mexico.

Canada has enjoyed generally good relations with the United States and likely will in the future. In matters pertaining to water, however, the picture is more problematic. David Durenburger, U.S. Senator from Minnesota and a staunch defender of the Great Lakes, has commented that water is a "political, not economic commodity". He also stated: "The first principle of water policy, in my country at least, is that rational thinking does not apply." These comments suggest that climate change and shortages caused by burgeoning populations make future bilateral relations uncertain.

Study Nine: Toxics and Human Health

Safe, clean water for drinking. While many people in the Third World do not have access to this most basic amenity, Canadians have long taken it for granted. In the last decade, however, alarm has grown over the presence of trace amounts of toxic substances in public water supplies. According to a recent national survey, 17 per cent of those polled rated their drinking water as unsafe and 13 per cent felt that bottled water was a preferable alternative to tap water. In 1991, Canadians spent over $150 million on bottled water and millions more on systems designed to treat water in their homes.

Are these concerns justified? The mere association of 'toxic' with the skull and crossbones symbol is enough to convince many that they are harmful, even poisonous. Yet chemicals have become pervasive components of our everyday lives and they have been welcomed for their benefits. On the downside, constant exposure to toxic materials in drinking water, food and air has become the norm. As in so many other instances, toxic materials are assessed in terms of their risks and benefits.

It should be noted that there is a definitional difficulty with the term *toxic*. The science of toxicology is based on the premise that 'the dose makes the poison', that is, that all substances are potentially toxic given a large enough dose. One example is salt, a metabolic necessity that can kill in extremely large amounts. As well, there are both naturally-occurring and synthetic compounds that can have effects on human or environmental health. *Toxics*, as used here, refers to a host of

synthetic compounds and heavy metals generally considered sufficiently harmful to warrant concern, if not regulatory control.

Just how big that range is can't be said. It has been estimated that there are over two million chemical substances world-wide, the vast majority synthesized by humans, and that this number is increasing at the rate of 2,000 every year. Some 63,000 of these chemicals are in commercial use (32,000 in Canada). The great majority of these are not known to be hazardous; equally, in many cases they are not known to be safe. The creation of chemicals has far outstripped our ability to determine all of their potential health effects. Various authorities have developed different listings for 'chemicals of concern'; for example, of the more than 1,000 hazardous compounds identified as present in the Great Lakes by the International Joint Commission, almost 130 are considered to pose significant health risks for humans and wildlife.

Balanced against these total numbers, the concentrations of toxic substances found in water are still extremely small, hence the term *trace* contaminants. Thirty years ago, a constituent with a concentration of one part per thousand (0.001) was considered trace. With an increase in the sensitivity of analytic methods, parts per billion (ppb) and parts per trillion (ppt) are now considered trace. PCBs (polycyclic chlorinated biphenyls) are routinely detected at parts per quadrillion (ppq) which, written out, is 0.000 000 000 000 001. Not surprisingly, our ability to detect such minuscule amounts has led to the discovery of far more substances than we had previously thought to be present. The question to be asked is, do these substances at these concentrations pose a significant risk?

Toxicity and Risk Assessment

The effect of a toxic substance varies with its potency or *toxicity* (which is inversely related to the amount required to cause a health effect), the *dosage* (the total amount ingested) and the *duration* of exposure. *Acute* effects, such as disability or death, are the result of short-term exposure (usually up to 96 hours) to low levels of a highly toxic substance or high levels of a less toxic substance. On the other hand, long-term exposure to minute amounts of a toxic substance can produce *chronic* effects, including behaviour abnormalities, certain cancers, genetic mutations and physiological or reproductive malfunctions in an organism (or its offspring). Assuming the same level of toxicity and duration of exposure, most highly toxic substances will produce either acute or chronic effects, depending on the dosage.

There are several ways that toxicity can be measured. The first is to establish the minimum quantity of a toxic substance that is lethal to 50 per cent of a test population over a prescribed period of time (say, 96 hours). This quantity is known as a *lethal dose fifty* (LD50) or *lethal concentration fifty* (LC50). This test is commonly used by the pesticide industry to ensure its products are effective

against target species and to determine if they are harmful to non-target species. A variation used in the regulatory control of pulp mill discharges requires that more than 50 per cent of fish must survive 96 hours of exposure to the effluent.

A second measure of toxicity is determined by subjecting test organisms to lower and lower doses to determine the level at which health effects disappear. This is referred to as the *No Observed Adverse Effects Levels* or NOAEL. There is a body of thought that says this is the threshold below which the natural repair mechanisms of the organism are able to, in effect, detoxify the material in question and that dose is therefore safe. However there is another body of thought that considers this apparent threshold to be no more than the shading from acute into chronic effects. Indeed for *carcinogens* (cancer-causing compounds) there is no dose that is considered absolutely safe, so testing tries to determine a *virtually safe dose* (one that poses a lifetime risk of causing just one case of cancer in a million people). However, in practise, this virtually safe dose can't be determined because it would require testing literally millions of animals.

Toxicity can also be measured by correlating known levels of chemical exposure with documented health effects in people and wildlife. Typically, this method uses the analysis of tissue samples to determine contaminant levels and was instrumental in establishing the link between PCBs and health effects in Great Lakes wildlife. However, these studies are very expensive and, particularly for humans, encounter difficulty establishing cause and effect. That a particular toxin is present does not provide conclusive proof of cause especially when there are other toxins present (as is often the case) and twenty years or longer may have elapsed between exposure and effect.

Toxicologic data from these and other methods are reviewed by Health and Welfare Canada, which in turn sets *guidelines* or limits for specified toxic contaminants in public drinking water supplies (other agencies set guidelines for overall surface water quality). As a general rule, Health and Welfare chooses the NOAEL level, then builds in a safety factor (typically lowering NOAEL by a factor of 1,000, but for carcinogens this factor may be even higher), both to protect the most sensitive members of a population and to guard against effects that were simply not observed. Even so, the lack of reliable data on cause-effect relationships between toxics and human health makes guidelines little more than informed best guesses. Nor are they comprehensive. Ambient water quality guidelines developed for the Great Lakes define only 43 hazardous substances, even though the known number is much greater.

Another difficulty is presented by the fact that drinking water is not the sole pathway of toxics into the human body. They are also consumed in the air we breathe and the food we eat. One study on organochlorine exposures in southern Ontario found that drinking water accounted for just nine per cent of total exposures. Food grown in the region was the main source, 86 per cent, with the remainder coming from the air.

Where sufficient evidence exists, government agencies may define what is considered to be a safe or 'acceptable' level of total exposure to a specified toxin. For example, an acceptable daily PCB intake in Canada is considered to be one milligram per kilogram (1 mg/kg) of body weight, or 50 mg for a person weighing 50 kg. The World Health Organization considers blood levels of mercury (in humans) up to 20 ppb acceptable. However, this doesn't mean that individuals with levels below or equal to these limits will suffer no ill effects, only that the existing scientific evidence has not determined that levels of this magnitude are, in fact, harmful.

Complicating the question still further is the possible synergistic effect of exposure to multiple toxins. For example, while toxin X is not carcinogenic of itself, it may promote the formation of tumours by toxin Y. And the combined effects of many toxics acting on the human body over a long period of time may damage the immune system. The plight of the St. Lawrence belugas provides support to this concern. In addition to abnormally high numbers of tumours, the whales were found to suffer from pneumonia, heart problems and stomach ulcers, all indicative of a weakened immune system. While they are not human, belugas may indeed be 'sentinels', along with the dozens of fish species exhibiting gross cancers and birds with deformed young, warning us of risks to human health in the same way that coal miners depended on the death of caged canaries to warn them of poisonous gases.

Those risks may be greatest for the unborn. A study of pregnant women who regularly ate contaminated fish from Lake Michigan found that their children had lower birth weights, smaller head circumferences and reduced attention spans. PCBs in the contaminated fish were implicated, but so were the pesticide toxaphene and a number of other chemicals.

Reviewing the evidence in 1991, the International Joint Commission concluded that, even at the trace levels at which they were found, toxics in the environment of the Great Lakes did in fact pose a threat to the health of the region's human inhabitants. But the Lakes are not the only region where health effects from toxics are either feared or known to have occurred.

Pesticides and Groundwater

Nearly 1.2 million people in Atlantic Canada rely on groundwater for domestic use. This resource is particularly important to the residents of Prince Edward Island because there is virtually no other source of fresh water. Other Atlantic provinces are not nearly so dependent. Two-thirds of the population of New Brunswick use aquifers as a municipal and domestic supply. In Nova Scotia and Newfoundland, the figures are 45 and 50 per cent respectively.

Agriculture is one of the region's primary activities. Nearly 7,000 hectares are cultivated in New Brunswick, and over 10,000 in Nova Scotia, mainly in the fertile Annapolis Valley. The most extensive development, over 108,000 hectares, is in Prince Edward Island. Farmers in all of these provinces grow fruit, vegetables and field crops (forage and grain), but the particular combination of soil moisture and temperature conditions have made potatoes the agricultural mainstay of the Maritimes. In 1985, the region produced one-and-a-half million tonnes of potatoes (half of Canada's total) worth $87 million.

Potatoes require intensive cultivation, and large applications of pesticides are the norm. One insecticide, aldicarb, has been used exclusively on potatoes, mainly in New Brunswick and P.E.I. Carbofuran, atrazine and dinoseb have been applied to other crops throughout the Atlantic provinces. Altogether, over 300 different kinds of pesticides are currently in use.

The problem with pesticides is that they represent a diffuse source of groundwater pollution. Much of the agricultural land in Atlantic Canada sits atop aquifers which, because their overlying strata are coarse and permeable, are highly susceptible to contamination. In 1985, aldicarb was discovered in 67 of 100 wells around Woodstock, New Brunswick, in levels between one and ten ppb (57 samples) and between 11 and 30 ppb (ten samples). Further testing from two field sites in P.E.I. revealed aldicarb concentrations ranging between one and 14 ppb. Thus, the farmers of New Brunswick and P.E.I (and possibly other Maritime provinces) face their particular version of the chemical dilemma: pesticide use has become part and parcel of their farming operations, but many see few ways to reduce this dependence even though they acknowledge the threat pesticide contamination poses to their drinking water.

Just how dangerous is aldicarb? The U.S. Environmental Protection Agency (EPA) considered aldicarb its most toxic registered chemical (levels exceeding ten ppb in drinking water are considered unsafe) and banned its use in states where rainfall was high and soils were acidic, relatively cold and extremely permeable. These conditions are prevalent in the Maritimes. Although aldicarb is still used in Canada, it has been labeled a *priority one* pesticide, meaning that it has a documented case history of having caused groundwater contamination through normal agricultural use patterns. Carbofuran, atrazine and dinoseb are also priority one pesticides, although their presence in groundwater in the Maritimes has yet to be detected.

Aldicarb is a *cholinesterase inhibitor* (a substance which interferes with the transmission of nerve impulses) and can be inhaled, ingested or absorbed through the skin. The LD50 for rats is .93 mg/kg (an LD50 of less than five mg/kg is considered extremely toxic). The *half-life* (the amount of time it takes for one-half of the original amount to break down) of aldicarb has not been firmly established, but it may persist in the environment for as long as one month.

Carbofuran has been used as a substitute for DDT, aldrin and chlordane and has a half-life of 30-60 days. This pesticide, which has an LD50 of eight to 14 mg/kg in rats, has mainly been used on corn, potatoes and vegetable crops. Atrazine is an herbicide which has been applied to strawberries, blueberries and grain crops and, in high concentrations, acts as a soil sterilant. Although it is only slightly toxic (an LD50 of 300 mg/kg in rats), it may be bioaccumulative. Dinoseb is an herbicide also used for weed control. This chemical is also highly toxic and inhalation may cause serious illness to the applicator. Dinoseb has a half-life of only two to four weeks, but has been known to contaminate streams and may be a threat to aquatic environments. All three chemicals are potentially hazardous to groundwater supplies.

In 1982, each Atlantic farmer used, on average, 500 kg of pesticides and 1,000 kg of herbicides. In New Brunswick alone for that year, farmers purchased 17,461 kg of aldicarb, 90,000 kg of carbofuran, 3,344 kg of atrazine and 104,532 kg of dinoseb. Nova Scotia sales amounted to 14,310 kg of dinoseb and 7,592 kg of carbofuran. Such figures are available because agricultural chemicals are registered in these two provinces. As of 1986, P.E.I. had not yet adopted this practice.

Public concern over groundwater contamination in the Atlantic region has prompted an extensive monitoring program and several surveys to assess the impact of pesticides on aquatic resources. As well, there have been studies to understand agricultural use patterns, and to determine pesticide accumulation and persistence in groundwater. New Brunswick is developing an aquifer protection program which will place strict controls on the application of pesticides over designated aquifers. Such measures are necessary to prevent the further contamination of aquifers because, once pollution has taken place, the offending substances are not easily removed. Although their numbers are still small, some farmers are turning away from their chemical dependence and employing less intrusive practises of *organic* or *sustainable* farming. But the next step, a general reduction in pesticide applications, is likely to be resisted by farmers and pesticide producers who see that as a route to lower yield and reduced profits.

Mercury in Northwest Ontario: A Case Study

Abundant in the earth's crust, metals are constituents of both terrestrial and aquatic ecosystems. While some metals (iron and magnesium, for instance) are essential for the proper growth and development of organisms, others, like mercury and lead, are non-essential and toxic, even in small concentrations. Over time, both land-based and aquatic organisms have developed tolerance for the concentrations of these various metals naturally present in their environment. Human activities, however, may raise these levels to the point that tolerance is exceeded.

The elements of most environmental concern are zinc, copper, selenium, mercury, cadmium, arsenic, lead and possibly silver, because they are inherently toxic and are common by-products in industrial wastewaters. Mines, smelting and refining industries, cement plants and sewer systems serving domestic and industrial uses are major point sources. Non-point sources include incinerators and metal-processing operations. Arsenic enters the environment mainly in the discharges of gold and silver mines. Selenium and cadmium are by-products of the extraction, smelting and refining of zinc, copper and lead. Lead was once an important ingredient in paints, but this use and its use as a performance-enhancing additive in gasoline have both been banned. Lead contaminates aquatic systems chiefly by atmospheric transport and urban storm drains. Arsenic and cadmium have also been used in the production of herbicides and fertilizers.

The hazards of mercury, as well as its uses, have been known for centuries. The Romans, noting that miners of the metal developed violent tremours, muscle spasms and character disorders, chose convicts and slaves to do the work. In the 18th century, goldsmiths employing mercury in their craft showed signs of vertigo and paralysis and rarely reached old age. The popular expression 'mad as a hatter' traces its origins to the tremours, manic-depressive behaviours and temperamental instability among hatmakers, who used mercuric nitrate to improve the felting quality of wool and fur. Today, mercury and its compounds are used in about three thousand industrial processes by over eighty industries. Two properties—its conductivity and liquidity at room temperature—make it ideal in making dental fillings, paints, electronic controls, thermometers, disinfectants, preservatives and lotions. It is also a catalyst in metallurgical processes and is used in the production of vinyl chloride, a component of plastics.

While the dangers of working with mercury have been well documented, its role as a significant environmental contaminant has only been recognized during the past 30 years. In the 1960s, the metal achieved notoriety following major outbreaks in Japan of what came to be known as Minamata Disease. This affliction, which led to severe illness and death, was eventually traced to the consumption of fish and shellfish contaminated by mercury-laden industrial wastewaters discharged into Minamata Bay. It took several years of research to determine that metallic mercury was being converted into an organic form, methyl mercury, by organisms in river and lake sediments. Methyl mercury is bioaccumulative and can reach significant levels in shellfish, predatory fish and sea mammals. Moreover, it is considerably more toxic to humans than its inorganic form as it is more easily absorbed into body tissues, concentrating in the heart, intestine, liver, kidneys and, ultimately, the brain. Here, it destroys cells in the cerebellum, which regulates balance, and in regions of the cortex associated with vision and personality.

Classic symptoms of mercury poisoning include numbness of the mouth, feet and hands; tunnel vision; loss of balance, memory and concentration; feelings of extreme fatigue; mental depression and emotional instability. These initial symptoms may eventually lead to severe disability, uncontrollable tremours and

convulsions, deformity, coma and even death. But its most insidious feature is that it can be transmitted through the placenta to the foetus. In Japan, concentrations of methyl mercury in infants at birth were 30 per cent higher than in the mother, and many were born with what appeared to be cerebral palsy. Some had deformed limbs and were seriously mentally retarded.

The World Health Organization (WHO) considers a mercury level of 0.5 ppm in fish to be safe for consumption, and this guideline has been generally accepted in Canada. WHO defines levels of mercury in the blood up to 20 ppb as acceptable*; individuals having from 20 to 100 ppb are* increasingly at risk*; and individuals with over 100 ppb are* at risk*, meaning that symptoms of mercury-related illness are likely to show up. But diagnosis can be difficult. The symptoms are not very specific and may resemble those associated with alcoholism, diabetes, malnutrition, old age and disorders of the central nervous system. Therefore, complete assessment of mercury poisoning can only be determined by autopsy. At the present time, there is no known treatment for mercury poisoning, although mercury levels fall over time as intake of the metal ceases.*

Considerable quantities of inorganic mercury now exist in the Canadian environment. While some of this comes from natural sources, a great deal originated from mining operations and chlor-alkali plants which produced, among other things, caustic soda and chlorine. Chlorine is an important bleaching agent used by the pulp and paper industry and, prior to 1970, large pulp mills often operated their own chlor-alkali facilities. Pollution controls were minimal and mercury concentrations in their discharges were extremely high by today's stringent standards. For example, between 1962 and 1970 (when new regulations for mercury discharges first went into effect) the Reed Paper Company at Dryden, Ontario, discharged an estimated ten tonnes of mercury into the Wabigoon River in northwest Ontario, affecting the English-Wabigoon river system, a waterway of some 480 kilometres in length. It was not an isolated example—similar amounts were released from chlor-alkali plants in Québec—but the poisoning of the Wabigoon came to be known as Canada's Minamata.

In 1971, the Department of Health and Welfare Canada began an investigation of mercury levels in fish and native people living downstream from Dryden. The area was remote and inhabited by Ojibwa Indians for whom the Wabigoon and English Rivers were not just the source of their staple food but were also an integral part of their culture. The fish samples showed concentrations of between 0.5 and five ppb. On the Whitedog Reserve, 22 of 65 people tested showed blood levels of mercury exceeding 100 ppb, with one individual having 600 ppb. Ten of 38 people at the Grassy Narrows Reserve had blood levels exceeding 100 ppb, with the highest at 319 ppb. Following these tests, commercial fishing along the English-Wabigoon system was banned and residents were advised by Health and Welfare officials not to consume locally-caught fish. But, without an alternative, consumption continued. It was not until 1975 that the province purchased freezers and began importing fish from non-contaminated areas. This action, more than

anything else, was responsible for the eventual decline in blood mercury levels among reserve residents.

Officials continued to monitor the two communities and in 1973, several individuals with blood levels exceeding 100 ppb agreed to be examined at Winnipeg General Hospital. After exhaustive testing, physicians reported they could find no evidence of mercury poisoning. However, in 1975, an independent examination found a wide variety of neurological symptoms that, although mild, were indicative of mercury poisoning. These findings illustrate some of the difficulties in assessing the impact of a toxic substance on human health. The term 'at risk' is relative; not everyone with blood mercury levels exceeding 100 ppb showed adverse effects, and one individual with blood levels of 600 ppb was not ill. As well, the clinical diagnosis was not conclusive, and further studies on the Whitedog and Grassy Narrows Reserves have failed to link mercury in the environment with any mortality.

If the medical evidence was inconclusive, the effect on the natives' lives was all too apparent. For a dozen years, the residents of Grassy Narrows had delivered thousands of pounds of fish to the Kenora Market. The ban on commercial fishing removed this cash income—a loss that studies have estimated at slightly over $400,000 from 1970 to 1990 and more than $10 million over the next seventy years. Not included in these calculations is the capital investment in boats and fishing gear and the closing of Ball Lake Lodge, a local attraction to sports fishermen from the surrounding area. Between 1970 and 1973, the Ontario government attempted to compensate 19 native fishermen with payments that averaged $311.08 per person. The total amount came to just $5,901 for the entire Grassy Narrows community.

Faced with irrefutable evidence of the dangers of mercury, the Ontario government ordered Reed Paper to immediately halt its mercury dumping in 1970. The firm said it would comply with the control order, but continued to pollute the Wabigoon River for another five years. In fairness to the company, it made a major effort to curb its discharges, holding its effluent in tanks and ponds on the mill property, then mixing the sediments with concrete and burying them in plastic-lined pits. But because Reed Paper was still using mercury, some of the metal invariably 'escaped' into the environment. (These losses were not insubstantial: between 1971 and 1974, nearly a tonne of mercury was lost into the air and water.) The alternative would have been to close the plant down, something company officials were not prepared to do.

The company's continued pollution of the Wabigoon River raised some disturbing questions about the ability of a provincial government to enforce its own regulations. The answer, in part, lies with the nature of the control order issued by Ontario's Ministry of Environment and the penalties for polluting under Ontario law. Reed Paper was given until 1974 to fully comply with the control order (a timetable mutually agreed upon by the company and the provincial government)

and was able to extend this timeline until 1975, when it planned to replace its mercury cells with new technology which produced caustic soda and chlorine without the use of mercury. The installation of the new treatment, however, was delayed by a lengthy strike at Reed and the company was again successful in negotiating extension of the control order to 1976. In the meantime, the government came under increasing pressure to take action against Reed, and when the second deadline passed—Reed's new equipment was still not in place—the Ontario Ministry of Environment finally charged the company with ten counts of causing "pollution dangerous to the environment and possibly human health". Rather than prosecute, the government extended the clean-up deadline another three years. It appears that the Ministry was reluctant to use its powers of enforcement, preferring to seek the co-operation of the company. But even if the government had chosen to prosecute, the maximum penalty under the law was a daily fine of $200. Extended over a year, the fines would have totalled $73,000, hardly a deterrent to curb Reed's practices.

Throughout the 1970s, company officials continually downplayed their role in contaminating the Wabigoon River. They argued that they did not become aware until 1970 that inorganic mercury used in the plant was potentially harmful to the environment, even though published reports on biomethylation (the natural conversion of inorganic mercury to methyl-mercury) were available as early as 1965. Moreover, they claimed that mercury biomethylated in the natural environment was much less harmful than the chemical substance that was directly discharged in Japan, an assertion that was later contradicted by experts in the field. In any case, the company argued, it was not responsible for health problems on the White Dog and Grassy Narrows Reserves. In a filmed interview in late 1975, Reed's president, Robert Billingsley, stated that no-one had told his company exactly what it had done or what the consequences of its actions were. The native people, in his view, were the responsibility of the federal government.

The question of responsibility was to surface again and again in the ensuing years. Despite its new technology, Reed Paper faced financial difficulties at the end of the decade, and sought to find a buyer for its Dryden plant. What made the sale difficult was the possibility that Reed would be forced to clean up the Wabigoon River and that it might be found liable for the health problems at White Dog and Grassy Narrows, and thus be forced to pay compensation. The Ontario government, for all intents and purposes, solved Reed's problem by assuming liability for mercury-related damages over $15 million, and the Dryden facility was sold to Great Lakes Forest Products in late 1979. What the government did not do was insist that the two companies seek a mediated settlement of pollution-related claims. Having been let off the hook, neither company has ever contributed to cleaning up the river nor to reimbursing the natives for lost income or illness.

Restitution to the reserves fell to the Department of Indian and Northern Development (DIAND). In 1976, DIAND officials announced a $920,000 program to create new employment opportunities at Grassy Narrows. Not to be outdone, the

Province of Ontario provided funds to build a day care centre and equipment for the band's logging operation. Over the years, Grassy Narrows people were also given preference in such job-creation programs as tree planting and fire fighting. All together, the Province spent about $440,000 on the reserve between 1972 and 1977. Neither of these efforts, however, has produced a sufficient level of social and economic reconstruction to bring the native communities back to their former strength.

The Ubiquitous PCBs

PCBs have been a known environmental problem in Canada for a number of years. Trace amounts of the chemical have been found in all parts of Canada, including the Arctic. Although not all long-term effects on human health are totally understood at this time, there is ample evidence that PCBs are highly toxic and can cause a range of adverse effects on aquatic life and warm-blooded animals.

When they were first developed in the 1930s, PCBs were used for a host of new industrial applications because they were conductive and virtually indestructible. Initially, PCBs were used as conductant fluids in electrical transformers, but their 'miracle' properties made them ideal as hydraulic fluids, specialized industrial oils, wood sealants and flame retardants. PCBs were also used in the production of pesticides, printing ink and carbonless paper. An estimated 5.7 million tonnes were produced in the United States prior to 1970, when the use of the chemical was restricted. Although PCBs have been used extensively in Canada, they were never manufactured here.

In 1968, the potential hazards of PCBs became widely publicized after more than a thousand people in southern Japan ingested cooking oil that had been inadvertently contaminated with the chemicals. While there were few deaths, a number of the victims began exhibiting symptoms now associated with PCB poisoning—chloracne and hyperpigmentation (skin disorders) and severe gastrointestinal disturbances. Children who had been exposed were later found to have retarded growth, changes in fat metabolism and blood enzyme levels, and problems with their immune systems and internal organs. In 1979, there was another mass poisoning, this time in Taiwan. A 1985 study of 117 children born to affected mothers showed them to be shorter and lighter than those of unaffected mothers. In addition, they exhibited a higher incidence of gum, teeth, skin, nail and lung abnormalities and had lower scores on developmental and cognitive tests and behavioural assessments. The oil in Taiwan contained about 100 ppm of PCBs, and even though the children had not yet been born, they were exposed to the chemical through the placenta or, after birth, through breast-feeding.

The manufacture, use and transport of PCBs in Canada is now controlled. In 1975, the federal government passed the *Environmental Contaminants Act* which restricts the use of PCBs to 'closed' systems such as electrical capacitators and

transformers. Amendments to the Act prohibit the manufacture of new PCB equipment and set limits on the amount of PCBs that can be released into the environment. Further, the *Transportation of Dangerous Goods Act* of 1985 requires that PCBs and PCB equipment be properly contained during transport. The latest legislation to be enacted is the *Canada Environmental Protection Act*, which seeks to create federal-provincial partnerships for 'cradle to grave' management of toxic substances, including PCBs.

Despite the plethora of legislation, PCBs are widely dispersed throughout the environment. Fifty per cent of North American production resides in landfills and waste dumps, and in Canada, 16,000 tonnes of the chemical are unaccounted for. PCBs show up in sewage sludge and in the effluents of wastepaper recycling industries. Waste oil, used in road resurfacing, has been both deliberately and accidently contaminated with PCBs contained in spent fluids from electrical or hydraulic equipment. Although accidental spills and leaks—349 reported in Canada—represent only one per cent of the PCBs released into the environment, their occurrence arouses public fear. On April 13, 1985, more than 450 litres of PCBs were spilled along a 70-kilometre stretch of the TransCanada Highway west of Kenora, Ontario. The chemical came from a leaking electrical generator being shipped by Hydro-Québec to a storage facility in Alberta. At least six people were directly exposed, and possibly thousands more who traveled the highway until it was closed 22 hours later. More disastrously, on August 23, 1988, three thousand residents of Ste. Basile le Grande were evacuated from their homes when a warehouse containing 1,500 barrels of PCB-contaminated oil caught fire. Following the accident, the Québec government placed an embargo on produce grown within the evacuation zone and confiscated local meat and dairy products. A water supply reservoir in nearby St. Bruno was shut off and nursing mothers in the Ste. Basile le Grande community were advised to stop breast-feeding.

PCBs are both persistent and bioaccumulative and, because of their volatility, can be transported in the atmosphere. Although not very soluble in water, PCBs tend to cling to organic matter in sediments. Surface water samples taken from the Great Lakes region show average PCB concentrations ranging from 0.015 to .04 µg/L, whereas bottom sediment samples are roughly ten times this amount. Fish have been found to have PCB concentrations ranging from 0.1 to 8 µg/g, depending on species and location. Based on these and other data, biomagnification through the food chain is thought to range from 2,700 to 274,000 times.

Extensive testing for PCBs after passage of the *Environmental Contaminants Act* revealed that the chemical was also distributed in the tissues of birds and mammals, including humans. For example, herring gull eggs contained 2-10 µg/g, Atlantic seal blubber 3.5µg/g, and Arctic polar bear fat 5.5 µg/g. The national average of PCBs in human fat tissue is .91µg/g. Human breast milk averaged 0.012µg/L nationally in 1975 and 0.022 µg/g in 1985, an 80 per cent increase. The data on PCBs also identify the Great Lakes region as being the most contaminated

in Canada. In addition, concentrations of the chemical are considerably higher downstream from cities and industries, suggesting that PCBs are contained in urban runoff and industrial effluents.

There is ample evidence supporting the adverse effects of PCBs in laboratory animals and wildlife. In fairly low concentrations (less than 5 µg/g), PCBs appear to alter enzyme function and cause liver and thyroid abnormalities. Levels of five to ten µg/g have been linked to reproductive failures in birds (shell thinning) and malformed foetuses in mice. Even plants, usually immune to organochlorines, may be affected. Levels as low as 0.005 µg/g have been shown to inhibit photosynthesis in phytoplankton. On the other hand, there have been few studies demonstrating that PCBs are harmful to humans at the levels found in water supplies and food. One investigation in Michigan, however, has linked consumption of PCB-contaminated fish by pregnant mothers with developmental and behavioural abnormalities in their newborn children. Consumption of PBC-tainted fish remains a concern for Canadians, particularly natives who traditionally consume large quantities of fish. Fish from the lower Great Lakes have PCB residues that occasionally exceed consumption guidelines of 1 µg/g. Assuming a single fish meal of 120 grams at this concentration, human exposure would be 120µg/g, a figure far in excess of the acceptable human intake of 1 µg/kg/day.

Despite new regulations governing the use and transport of PCBs, the chemical will likely be with us for a long time. Unlike DDT, which had a market that could be legislated out of existence, the very ubiquity of PCBs has made them all but impossible to eliminate. They are in the air we breathe, the water we drink and the food we eat. They are in electrical generators and transformers across the country. They reside in dumpsites, some of which we do not even know about. And they sit in warehouses waiting for incineration or an accident like Ste. Basile le Grande. It will be a long wait for the former. At the present time, there is only one facility in Canada—the hazardous waste disposal plant in Swan Hills, Alberta—with the capacity to destroy PCBs by incineration. The Alberta government, which has a policy of not accepting hazardous wastes from outside the province, was nevertheless asked to dispose of the remaining PBCs from Ste. Basile le Grande, and has received several other requests from storage sites in Ontario. The Alberta government refused to change its policy. The success of a decision to ban a substance depends on the ability to eliminate it, a lesson that will become even more obvious as society considers banning still more.

The Chemical Quandary

As we have seen, industrial processing accounts for the majority of toxic substances released into the environment. While industry as a whole has been criticized for its polluting practices, one major sector—the chemical sector—has often been singled out as the worst offender. Like other industries, chemical companies produce wastewaters that contain toxics. The difference is that they

also produce products which, in their own right, are inherently toxic. In recent years, the industry has struggled to maintain its image in the face of growing public skepticism and criticism that the industry's priorities are misplaced.

Dow Chemical Canada Ltd. is the second largest producer of chemicals in Canada, with annual revenues of $1.63 billion. Once considered among the worst polluters in the country, the company has been forced to redefine its ideas about environmental protection and its future in commercial chemistry. A look at the evolving corporate culture of Dow gives us an insight into what might be expected from the company—and the chemical industry—in the years to come.

The Dow story begins in 1897, when its founder Herbert Dow started extracting bromide from underground brine pools. Soon after, the company expanded its operations, manufacturing Epsom salts, carbon tetrachloride (a solvent used in dry cleaning) and pesticides. In 1938, Dow began making plastics. One of its most profitable inventions, Styrofoam, was widely used as an insulating material, and Saran Wrap, developed in the 1950s, became its best-known consumer product. Although the slogan "Better living through chemistry" was likely coined by Dow's chief rival, the du Pont Corporation, it characterized Dow's transformation of mid-century North American lifestyles.

In the 1960s, Dow's chemical cornucopia began to look more like a poisoned chalice. First, it supplied the U.S. Air Force with materials used in the production of napalm, a jelly-like incendiary used against Vietnamese revolutionaries and civilians. A second substance, Agent Orange, a defoliant containing the herbicides 2,4-D and 2,4,5-T, was sold to the U.S. Army. Years later, Vietnam veterans launched a class action suit against Dow claiming that dioxin, a by-product of Agent Orange, had caused cancer, foetal abnormalities and skin diseases. Evidence presented at the trial indicated that company officials had prior knowledge of dioxin's hazards, and Dow was forced to pay the veterans $180 million (U.S.) in compensation. In 1970, Dow's Sarnia plant was blamed for unacceptably high levels of mercury in Lake St. Clair and western Lake Ontario. Following an unsuccessful $35 million lawsuit by the Ontario government, the company paid $400,000 to Lake Ontario fishermen in an out-of-court settlement. Then, in August 1985, Dow's Sarnia plant spilled 11,000 litres of perchloroethylene into the St. Clair River and, just a month later, an oozing 'blob' of congealed chemicals was discovered on the river bottom. A million dollars were spent in the clean-up. In 1990, after two more spills into the St. Clair, the company was issued a Director's Order by the Ontario Ministry of Environment requiring it to meet certain clean-up targets within the next year.

Prior to the 'blob', the company had seemed immune to its critics. Today, company officials point to it both as a public relations crisis and as a pivotal point in the company's environmental thinking. Dow's new mission—the virtual elimination of wastes—forms the agenda for several company initiatives of which a key element is what the company calls "river separation". First applied to their facility at

Varennes in Québec, river separation involves redesigning plant operations so that there is no direct discharge of either wastewaters or storm-drainage into nearby waterways. For Dow's Sarnia operation, river separation is a ten-year, $100 million near-total re-engineering of a plant originally designed to dump wastewaters into the St. Clair River. Planning has also started for river separation of the company's plant in Fort Saskatchewan, Alberta. Additionally, spending on air and water pollution abatement technology doubled between 1989 and 1990, and there are dozens of internal changes—environmental values instilled at the core of management policies, operating standards beefed up with new environmental guidelines, and employees monitored for environmental performance.

Still, Dow has its critics. Environmentalists question spending millions on preventing the release of toxic substances when the company continues to create them. Given the growing evidence that many of the industry's products are harmful, they argue that zero discharge programs like Dow's simply sanction the continued use and manufacture of these products. Rather, they argue that companies like Dow should be looking for safe alternatives to their most dangerous chemicals (see Table 6 overleaf) or *sunsetting* them, that is, phasing out their production altogether.

Sunsetting makes Dow nervous. Having committed considerable cash to the reduction and containment of wastes, the company does not want to suffer the financial repercussions of withdrawing from production those chemicals it does not or will not believe are bad. Instead, it has joined an industry-wide program which emphasizes the safe use of chemicals, including their proper application and disposal. The company is also conducting research aimed at eventually replacing chlorinated solvents with water-based solvents. Although environmentally-safe chlorine alternatives do exist, they are very expensive to produce, and companies like Dow remain unconvinced that their customers are willing to accept these increased costs.

Economics aside, Dow will probably continue to produce perchloroethylene, vinyl chloride, methyl chloroform, styrene and other organochlorines because its corporate culture is founded on a trust of chemicals. Its executives and engineers believe in the science of 'no observable effects'. And they also believe that consumers want the chemicals Dow produces because these chemicals contribute to a better quality of life for everyone. As one company executive has stated, "We are nothing more than an industry that uses the resources of the earth, reshapes the molecules and makes them into useful articles for society."

A basic axiom of public health is that it is preferable to prevent illness rather than treat it. Applied to the toxics question, that suggests maximum efforts should be made to reduce exposures. While this premise is embraced by virtually everyone, consensus breaks down on the question of how it should be achieved. The chemical industry maintains that chemicals enhance the quality of our lives and that the most practical means of reducing exposure is to limit their entrance into

the environment. They argue that virtual elimination programs like Dow's, and the industry's Responsible Care program, which encourages proper use and disposal of chemicals, provide both economically and environmentally sound levels of prevention. But environmentalists argue that these programs do not go far enough, that there will always be escape of materials during their production, transport, use and disposal. True prevention, they argue, can only come with *zero use* and those chemicals which are known to cause harmful effects should be sunsetted immediately.

Table 6: Chemicals Produced by Dow's Sarnia, Ontario, Plant

Chemical	% of Dow's Production	Use for Society	Harmful Effect
Chlorine	23%	Widely used in manufacturing other chemicals such as bleach and water purifiers	Creates organochlorines which are linked to cancer and birth defects
Vinyl Chloride	5%	Used in polyvinyl chloride for sewer pipes	Known carcinogen
Methyl Chloroform	under 5%	Solvent for metal degreasing	Probable carcinogen
Perchloroethylene	1%	Dry-cleaning solvent	Possible carcinogen
Carbon tetrachloride	under 5%	Solvent used to make air conditioning and refrigerator coolants	Probable carcinogen
Styrene	5%	Makes polystyrene; used in making epoxy resin and latex	Probable carcinogen
Ethylbenzene	7%	Used to make styrene	Long-term exposure hazardous; made with benzene, which is a carcinogen

Source: Report on Business Magazine, November, 1991

If history provides any guidance, the dynamic is on the side of sunsetting. Historically, pollution control for toxics was based on limiting their concentrations in effluents. But the uncertainty over the effects of toxics on human health and the difficulty and expense of removing incrementally smaller amounts of toxics makes this approach questionable in the long term. More recently, we've opted for the virtual elimination of toxics by restricting the discharge of contaminants into the environment. But toxic chemicals contained in surface runoff also contaminate

water. And the total elimination of these non-point sources can only be accomplished if we stop manufacturing and using the chemicals in question. Adopting a strategy of zero use is certainly a bigger step than zero discharge programs like Dow's. But zero use depends less on technological innovation than on society resolving the chemical quandary. Are we prepared as a society to forego the benefits of chemicals and suffer the economic consequences of curtailing their production? Or should we continue to support an industry with a history of environmental negligence that is trying to improve both its way of doing business and its public image?

Study Ten: Water and Sustainable Development

In 19th century England, rural towns and villages set aside a community pasture for the grazing of cattle and sheep. This pasture was called a *commons* because anyone could have access to it. The problem with the commons was that people could use it without being responsible for it. And so, when certain individuals put too many animals on the pasture, it was overgrazed and its value to everyone was reduced.

Today, this analogy extends to all of the globe's 'common' resources—air, water, soil and forests. All of these resources have a limited carrying capacity—that is, they can only support a certain level of use, and if this level is exceeded, the resource loses the capability of regeneration. The use is *unsustainable*. Although water is replenished by nature, there are limits to the amount we can withdraw, consume and pollute before we exceed its carrying capacity.

Applied to water, *sustainable use* means the utilization and management of the resource so as not to compromise its life-supporting capabilities. At the heart of the idea is the recognition that water is both a finite resource and a fundamental part of the biosphere, the integrity of which must be preserved. So far, the concept of sustainable use has not been universally accepted in Canada and, indeed, in the rest of the world. Instead, we largely continue to follow the traditional supply-oriented water management practices of dam building and waste assimilation, predicated on the assumption that water exists in infinite quantities and that its overiding purpose is to serve the social and economic needs of human society.

This *supply management* can be considered shortsighted in several respects. First, it tends to ignore the financial costs of water development and, in particular, the fact that developing systems to supply ever larger amounts of water and remove ever larger amounts of contaminants from wastewaters is becoming prohibitively expensive. Moreover, these costs are often externalized (they are not factored into production) and thus are passed on to society as a whole. The deterioration of water quality in the lower Great Lakes is a clear illustration of these *externalities*.

Long used as a dumping ground for municipal and industrial waste, these lakes were 'saved' from eutrophication at great public expense. Pollution control requirements have, to a degree, internalized these costs but those same requirements have also sanctioned externalities by allowing the continued discharge of wastes. Some estimates for cleaning up toxic contamination of the Great Lakes (caused by decades of cost externalization) exceed $100 billion.

A second and related problem with supply management is that it tends to encourage overconsumption by providing water at bargain prices. Water has long been considered to be a *free good* rather than a commodity and, while we do pay for water, we usually pay for its treatment and delivery rather than the water *per se*. Economic theory tells us that when a good is undervalued, it tends to be overused. This same principle applies to water: we use large amounts (perhaps wastefully) because it is cheap, whereas if it were more expensive, we would tend to conserve it. To further extend this idea, the low price of water encourages greater consumption, which in turn leads to the expansion of water supply systems (e.g. larger water and wastewater treatment facilities and water storage projects). These systems are economically unsustainable (the cost of water is too low to pay for them) and therefore have to be supported by government subsidies.

A third problem with supply management is that it leads to the destruction of aquatic ecosystems as well as the social and economic fabric of entire communities. This appears to be true of most major water storage projects undertaken in Canada over the last twenty years, and is the major finding of environmental impact assessments associated with the James Bay, Rafferty-Alameda and Oldman Dam developments. While mitigative measures offset some of the impacts, they are usually identified after a project decision has been made and thus are not factored into the project's initial costs. In some cases, the full impacts of development were not realized until years later, and compensation, often provided at a cost to the public, became significant.

But supply management's most telling drawback is its failure to acknowledge the right of future generations to enjoy the benefits that water presently affords. Every time we pollute a river or lake, drain a wetland, or deplete or poison an aquifer, we diminish this possibility. What makes some developments particularly onerous is that they destroy traditional native livelihoods that are based on a healthy water environment and have long been, by their very nature, sustainable. The short-term exploitation of water resources is akin to deficit financing: we may enjoy the immediate benefits of an improved standard of living today but the debt, a degraded environment, will be paid for by our children and grandchildren in the form of a lower standard of living.

Throughout these studies, we have discussed instances of water-related developments with heavy environmental impacts that have nevertheless been justified on the grounds of employment and the opportunity for economic and social growth. In an era of struggling national and provincial economies, these

rationales are politically and financially attractive. On closer examination, however, it is impossible to separate economic development from environmental issues. Many forms of development erode the environmental resource upon which they are based, and environmental degradation can, in turn, undermine economic development. These facts have led to another view: that economy and environment are interdependent and inseparable, and to ignore one is to jeopardize the other. Stated somewhat differently, the economy and its partners exist within the environment, not outside it. Economic prosperity cannot be maintained unless we protect the environment and our resource bases, which are, after all, the building blocks of development. Correspondingly, economic growth and prosperity provide us with the means to manage natural resources wisely and protect environmental quality.

This interdependency has obvious relevance to our management of aquatic resources. Water is both an integral part of the environment and a resource that supports economic growth. Abusing the resource results in lost economic opportunities and an overall deterioration in environmental quality. As well, practices that degrade other resource bases, such as air and soil, also affect water, and the effective management of aquatic resources merges into the larger issues of properly managing all sectors of the economy.

The acid rain problem is a case in point. Technically, acid rain is caused by air pollution, and while it destroys the ecosystems of lakes, it also damages forests that provide thousands of jobs for people. With these externalities taken into consideration, acid-forming discharges from smelters and coal-burning thermal plants are neither environmentally nor economically sustainable. The same argument could be extended to other sectors as well: clearcutting forestry practices erode the land and degrade water quality; pesticides threaten entire species of aquatic life; certain farming and irrigation practices accelerate soil erosion and salinization; and, when improperly managed, landfills and waste dumps leach toxic chemicals into the water supply. (Closer to home, our dependence on the automobile creates not just acid rain but urban smog, and contributes to climate warming.) If the sustainability of all these practices is suspect (and it is), then how sustainable can the society they support be?

Clearly, we must adopt practices of resource utilization which allow development to occur within the limits of nature. This linkage provides the basis for the concept of *sustainable development*, which is generally defined as development that ensures the use of resources today does not diminish the possibility of their use by future generations. (The fullest exploration of sustainable development remains the book *Our Common Future, The Report of The World Commission on Environment and Development. Report of The National Task Force on Environment and Economy*, Canada's response to *Our Common Future*, is also instructive.) Achieving sustainability necessarily involves the protection and preservation of our water resources, and the rethinking of practices which exploit and degrade them. Radical departures from the status quo are required, and their adoption will necessitate

shifts in our thinking, not only about water and the way that we use and manage it, but about economic growth, our overall quality of life and our place and role within the ecosystem.

Demand Management

Water management in Canada has tended to meet the growing demand for water by increasing the supply. Alternatively, water could be managed to match demands with the available supply. What this means in practice is reduced consumption, more efficient water use and the production (and hence discharge) of fewer wastes. These kinds of strategies fall collectively under the heading of *demand management* and while demand management is but one concept for achieving long-term sustainability, it is fairly well understood and has been adopted by a number of water-using sectors.

An obvious way to discourage waste and promote more efficient use of water is to charge a price for it that more accurately reflects its value. In Canada, water is metered in about two-thirds of municipalities, including most of the larger ones. And it works. In the Durham region of Ontario, per capita consumption fell by 23 per cent after metering began. Edmonton, which meters all residential users, consumes, on a per capita basis, half as much water as Calgary, where only 19 per cent of residences are metered; those parts of Calgary that are metered show consumption rates similar to those in Edmonton. Overall, metering in municipalities reduces consumption between ten and 40 per cent, particularly during summer use.

However, even when water is metered, municipalities usually charge *declining block* rates for water, that is, the price per unit decreases with the amount used. The rationale for this practice is that larger users, typically industries, are subsidizing water charges for smaller users such as homeowners by paying a larger share of the delivery system's capital and operating costs. In truth, larger users are often responsible for the size of a water system, and smaller users may in fact be subsidizing the larger ones in an oversized system that does not directly benefit them.

Demands for water do not remain constant, and for this reason, water supply systems are usually designed to meet *peak* rather than *average demands*. During the summer, for example, people like to wash their cars and water their lawns, activities which stretch the limit of treated water supplies (rationing, in fact, is sometimes due to the inability of a water system to supply treated water rather than the lack of raw water supplies). Some observers have advocated *increasing block* rate structures which would charge more per unit for high rates of water consumption, particularly during peak demand periods.

Charges levied on wastewater discharges may also act as an incentive to treat wastes more effectively, or even to produce fewer of them. In Winnipeg, effluent surcharges were an effective means of persuading packing houses and other factories to pre-treat their wastes before sending them to municipal sewage facilities. British Columbia has instituted waste disposal charges based on the kind of industrial processing and types of waste products. The province expects to raise $1.25 million in fees annually, and will apply them to ambient water quality monitoring programs.

Water pricing could also be applied to irrigators. In the Okanagan region of British Columbia (where water is relatively a scarce commodity), some irrigation farmers are charged between $50 and $100 per acre ($123 and $247 per hectare). To offset the high cost of water, many are using drip irrigation systems, which are considerably more efficient than sprinklers. Some districts have seriously considered farm metering as a means of reducing the demand even further, and the B.C. government has proposed that water licenses be cancelled in instances where water is being used wastefully. Water also costs more in the Okanagan because irrigators pay a larger percentage of the costs of water development.

In Alberta, where the government subsidizes irrigation development, farmers pay a much lower percentage of this cost (between $3 and $12 per acre, or $7.41 and $29.65 per hectare). The escalating demand for water in major irrigation districts in Alberta seems to be pointing toward farm metering, although farmers here are still resistant to the idea. Such reluctance may be associated with the view that water is still plentiful in Alberta. But irrigation farmers have also argued that if metering was adopted, they would be entitled, like municipal users, to a supply that was both dependable and sufficient to meet their crop requirements. This argument tends to ignore two realities. First, municipalities with mandatory home metering still ration water when it is scarce. Second, irrigation districts in Alberta are not always capable of providing water on demand because of system losses (canal seepage, spills), and even with modernization, these districts will continue to supply the majority of their ratepayers with water delivered in open-ended rather than closed systems. Furthermore, most irrigation farmers grow grain and forage crops, and out of necessity use sprinkler systems that are less efficient than drip systems.

One of the problems with water pricing is determining its fair market value. Water's price is said to be *elastic* because it varies with time and place, and people may be willing to pay more for water, depending on the intended use and the economic value of that use. Water free of toxic contaminants, for example, may command a higher price than water that isn't. In areas of the southwestern United States, where water rights are now allowed to be bought and sold, the higher price that industries and municipalities are willing to pay is shifting water rights away from irrigation. Farmers can make more money selling their water than using it to grow crops. In Canada, water is a publicly-owned resource and there are questions of social equity (should the poor be forced to pay high rates for a basic necessity?)

and regional fairness (should people in areas of water scarcity pay higher rates than those in water-rich areas?) While water pricing is certainly a part of demand management, it is not easily applied.

Water consumption can also be reduced by using water more efficiently. One popular method in municipal water conservation programs is *retrofitting*—the installation of water-saving devices such as low-flow shower heads and toilet dams (devices that reduce the amount of water stored in the tank). Conventional shower heads, for example, use between 13 and 19 litres of water per minute. More efficient heads reduce this flow to between five and seven litres per minute without sacrificing performance. Similar devices can be installed on faucets to cut water flow by as much as 85 per cent. Standard toilets use about 20 litres per flush; more efficient toilets use as little as four to six litres per flush. Soaker hoses, which use up to 50 per cent less water than conventional sprinklers, are just as effective for watering lawns and gardens.

A decrease in domestic and municipal water consumption, whether through metering, retrofitting or other mechanisms, can reduce water withdrawals. More important, costly expansion of water supply systems can be delayed or, in some cases, avoided, particularly if peak demands are reduced. Less water consumption also means the production of less sewage (about 80 per cent of water used in homes flows into sewers), thus saving on the expansion costs of wastewater treatment facilities.

Reducing water consumption can also result in significant savings for industries. The re-circulation of water in cooling towers can cut consumption by up to 90 per cent, a significant amount considering the volumes withdrawn by thermal-electric power plants. Reclamation and reuse of water in manufacturing processes also saves on consumption. As well, many new industrial processes use water more efficiently. For example, the production of a tonne of steel can require between 5,000 and 250,000 litres of water, depending on the type of equipment that is used and the degree of water recycling. The manufacture of products from scrap instead of virgin ore also can reduce water requirements, up to 97 per cent in the case of aluminum.

Our previous discussion of irrigation practices looked at mechanisms that depend in large part on the capabilities of the system to improve the efficiency and dependability of water delivery. Reduced consumption may also depend on the individual abilities of farmers to apply just the right amount of water to the crop at the proper time. This concept is known as *irrigation scheduling* and involves the measurement of soil moisture and the calculation of specific crop requirements. Not all farmers are familiar with these methods, and many may be reluctant to abandon practices that are more 'comfortable'. Education is clearly the key, both to acquaint farmers with new technologies, and to convince them that they can improve crop yields while saving water.

These various water conservation strategies are primarily aimed at reducing overconsumption and waste, but a more intractable problem presents itself when population growth—and its resulting demand for water—begins to outstrip the available supply. That was the experience of the Regional Municipality of Waterloo, one of the most rapidly growing areas of southern Ontario in the mid-1980s.

Located seventy miles west of Toronto, the Regional Muncipality is a form of metropolitan government for an area that includes the cities of Kitchener, Waterloo and Cambridge. The Region wholesales water to the cities who in turn retail it to their residents and businesses. After several years of study and argument over the impending water shortage, the Region decided that both supply augmentation and a major conservation program were required. Among the bylaw changes made to enforce conservation was a ban on once-through cooling water and the stipulation that any lawn watering bans would automatically last for ten days (bans were imposed in 1988, 1989 and 1991). Changes were made both in the means of pricing water and its cost: declining block rates were eliminated and the Regional Government boosted its wholesale price to almost two dollars per thousand gallons (a little more than four cubic metres). Correspondingly, the retail price increased, to $4.40 per thousand gallons for the City of Cambridge.

The changes in pricing provided effective motivation for large companies to cut their water usage. In 1989, J.M. Schneider Ltd. (a meat-packing company and one of the area's oldest and largest employers) was using 470 million gallons of water (about 2.1 billion litres) a year. With its costs boosted by almost 40 per cent, the firm extended its existing water conservation program. In two years, it was able to cut its use to 325 million gallons (about 1.5 billion litres—a reduction of 30 per cent) and the program is continuing. Reaching homes (where daily per capita use is 45 gallons—a little over 200 litres) has proven more difficult. In addition to media campaigns aimed at the general public, more than 60 thousand active retrofit kits (with toilet dams, low-flow shower heads and faucet flow restrictors) were distributed through the schools and directly to homes. But surveys in Cambridge showed that just 48 per cent of kits delivered to homes were actually installed (with people who said they were going to install, the figure rose to almost three-quarters).

On the supply side, the Region opted for the Mannheim Project—the construction of a weir on the Grand River, a pumping station, reservoirs and a groundwater recharge scheme, projected to cost $69 million. The final cost was in the order of $170 million, but that bought the Region far less than anticipated. The municipality projected that the Mannheim Project, coupled with the conservation programs, would ensure adequate water supplies for 50 years. But mushrooming growth and underestimates of groundwater supplies have already reduced this to perhaps as little as ten years. Future supply augmentation alternatives include the construction of a pipeline to Lake Huron at an estimated cost of $400 million (this could be reduced if the Region tapped into a mooted regional pipeline from the same

source intended to supply Toronto and other southern Ontario communities with water not contaminated by toxic chemicals).

Whether regional pipelines in southern Ontario are feasible, just from a supply point of view, is questionable. The renewable supply of the Great Lakes is only one per cent of its total volume, and some projections show consumptive demand exceeding this within fifty years. Bringing water from Lake Huron, which is much less polluted than Lake Erie or Lake Ontario, raises questions not only about the ultimate impacts of industrial wastes on drinking water but how long Lake Huron will remain unspoiled. In microcosm, we see the same problem that is facing North America as a whole. The quantity of water is finite; growth must eventually be brought in line with supply, and that will mean much higher prices for water and a considerable reduction in our consumption.

These kinds of strategies will likely be resisted unless we think they are absolutely necessary, unlikely considering the popular perception that water is plentiful and cheap. In contrast, oil is neither plentiful nor cheap. During the oil 'crisis' of the mid-1970s, efforts were made throughout the economy to conserve energy in order to offset higher prices and to use less of a strategic commodity that was controlled by foreign markets. The effects on industrial processes, housing designs, automobiles (smaller, more fuel-efficient cars and lower speed limits) and public sensitivity have been profound. As a result, the growth in energy demand was dampened. While the rationale for conserving water may be different, the opportunities for controlling demand are comparable.

Waste Reduction

The conventional approach to pollution control is to limit the discharge of wastes to levels deemed to be within the receiving waterway's assimilative capacity. This amounts to an economic subsidy provided by the permitting authority to municipalities and industries that encourages the continued dumping of wastes. In the longer term, it may be more sensible to produce fewer wastes and, ultimately, no wastes at all. This idea is often criticized as being economically and technologically unrealistic. Yet wastes, if recycled or reused, represent a resource in their own right. Strategies to reduce or eliminate wastes begin, not with treatment, but with the very processes that produce them in the first place.

One way of reducing pollution is to reduce the quantity of wastes produced. Electronics firms, for instance, can reduce the amount of solvent used to de-grease metal parts, while electroplating companies can make changes that will allow rinse water to be reused several times. Another strategy is to reuse chemicals and solvents that otherwise simply might be discarded. Waste alkali produced by one company can be used to neutralize acids at another company, and cement dust captured by the pollution control equipment of a cement kiln can be employed in the drying and stabilizing of sludges that might leach from a landfill site. A third

option is to recycle. Process chemicals can be treated, then used in some other capacity; combustible waste solvents can be burned, and the heat that is generated can be applied to other production processes; and precious metals can be removed from plating or photographic wastes and sold. A fourth strategy, research and development, pilots new waste-reduction methods. As an example, one company has developed an anaerobic digestion process which is used to decompose whey, a by-product of cheese manufacturing. Cheese whey produces a BOD 350 times stronger than domestic sewage, placing severe demands on municipal wastewater treatment plants. On-site anaerobic treatment not only reduces this loading (thus avoiding the surcharge many communities put on high BOD wastes) but also produces methane gas, which can be used as a fuel. This 4R approach (reduction, reuse, recycling, and research and development) has been widely adopted.

Waste reduction is also profitable. The Pollution Pays Program, endorsed by the United States and Germany, is based on the concept that the reduction, reuse and recycling of wastes is cheaper than the cost of purchasing and operating pollution control equipment. In the U.S., the 3M Company eliminated over 76,000 tonnes of air pollutants, 13,457 tonnes of water pollutants, over two and a quarter billion litres of polluted wastewater and 3,000 tonnes of sludge per year, netting them a total savings of $17.4 million over three years. Union Carbide's Surplus Products Group, which handles new markets for by-products and wastes, sold over 18 million kilograms of materials in 1973, recovering almost $1.25 million from sales and unneeded disposal technology. Monsanto Chemicals is marketing millions of kilograms of by-products from chemical processes estimated to have a market value of $350 million. And Dow Chemical's Midland Division saved six million dollars over a three-year period on materials previously lost to sewers.

Two other recycling measures hold promise for the future. One is the use of municipal sewage effluent for irrigation. *Effluent irrigation*, as it is commonly called, utilizes the nutrients in wastewater as fertilizers instead of putting them into waterways where they can cause eutrophication and other problems. The idea is not new. Before water closets were invented in urban Europe, the contents of chamber pots and privy vaults were collected as 'night soil' and carted to nearby farm fields. The practice was discontinued after toilets became popular and it became much simpler to run household wastes into municipal sewers and hence into nearby rivers. Today, effluent irrigation is employed in Cranbrook, B.C., Swift Current, Saskatchewan, and in a number of smaller communities across the country. Even so, the practice has limited application. Very large tracts of land are required to accommodate the huge volumes of wastewaters produced by large urban centres. As well, unless sterilized, bacterial contamination of sewage effluent precludes its use on vegetable and forage crops. And hazardous materials present in the sewage—heavy metals, industrial wastes and domestic poisons like paint, solvents and pesticides—can build up in the soil, making it unsuitable for cultivation.

Sludge, the solid residue from sewage treatment, has been put on the land as a soil conditioner, buried in landfill sites or, in some instances, dumped into the ocean. None of these alternatives is without problems. Canada produces some 500,000 tonnes of sludge annually and spends $100 million each year to dispose of it. Recently, we have found that sludge can be converted to oil. In a process developed by the Wastewater Technology Centre in Burlington, Ontario, dried sludge is heated to temperatures of 300 to 350°C for about 30 minutes in an oxygen-free environment. The oil that is produced can be sold on the open market. At $30/barrel, the 700,000 barrels this country could produce represents a potential annual savings of $20 million. Although the process is expensive, it is cost-effective for communities that produce large volumes of sludge and lack sufficient landfill disposal sites. Among the cities examining the technology is Halifax, which has traditionally dumped its sludge at sea.

Not all wastes, however, can be reused or recycled. In these cases, we have tried to improve wastewater treatment technology to the point where the impact of contaminants is minimized. As previous studies have pointed out, however, even the most advanced technologies have their limitations because they cannot remove all contaminants that are or could be harmful to aquatic life or to human health. Furthermore, to argue that the use of advanced technologies to control pollution constitutes a legitimate approach to sustainable development ignores the central premise of sustainability—the very-long-term protection of the environment and its regenerative capacity.

Rather than focussing on a search for technological fixes, we may be wiser as a society to move away from products that are potentially harmful to the environment or that create toxic wastes during their manufacture, use and disposal. There is fairly convincing evidence that consumer demands can influence production processes in favour of more environmentally-benign substitutes, such as phosphate-free detergents and non-chlorine-bleached (or unbleached) papers. Since 'green consumers' have the power to influence producers in ways that government regulations cannot, purchasing decisions must be combined with commitments to the reduction, reuse and recycling of all products.

The Institutional Challenge

Demand management strategies are appropriate to sustaining the integrity of the water resource because they seek to reduce consumption and pollution in ways that do not diminish quality of life or the economic incentives that allow continued development. They are part of the solution. But we must also look carefully at the nature of decision-making in Canada, and in particular, how legal and institutional systems are responding to the challenges of sustainable development.

In this country, elected legislatures and parliaments have the authority to enact laws to govern resource development and to protect environmental quality. Laws

tend to be less effective, however, when they are designed to achieve a balance between competing interests. Pollution control, for example, is hampered by the fact that governments are attempting to simultaneously achieve two often contradictory aims: to safeguard human and environmental health, and to maintain the efficiency and productivity of businesses for the broader benefit of society as a whole. Sustainable development is predicated on the notion that both aims not only can be, but must be achieved. In practice, it remains difficult.

The MISA (Municipal/Industrial Strategy for Abatement) program in Ontario clearly illustrates this dilemma. The ultimate goal of MISA, announced by the provincial government in the late 1980s, was the virtual elimination of persistent toxic chemical discharges. The program's cornerstone, the setting of legally enforceable effluent standards, represents a departure from established practice in Ontario, where water pollution control had been based on non-enforceable guidelines and pollution control orders negotiated with individual polluters. The program also established monitoring and abatement regulations aimed at assessing whether effluent standards would be sufficient to protect water quality and at a more rigorous approach to prosecuting polluters.

Despite its lofty goals, the program has been difficult to carry out. Part of the reason lies with the province's decision to base discharge standards on BATEA—best available technology, economically achieveable—an approach which may encourage adoption of technologies that are less effective in curbing pollution. The program has also encountered resistance from industries, which claim that MISA will impose high costs, causing them to lose their competitive edge and perhaps forcing plant closures. In the long term, some industrial polluters may find the risk of incurring fines preferable to the cost of abatement.

On the other hand, companies like Dow have gone one step further by instituting their policy of zero discharge. Dow may be responding to what it sees as the inexorable movement of society toward the elimination of all toxic discharges. Still, the company's efforts appear to be more pro-active than initiatives like MISA and the Great Lakes Water Quality Agreement of 1978.

The policies and laws governing water allocation have long favoured licensing of withdrawal uses on the premise that the most valuable use of water was to support economic growth. Recently, the Alberta government began implementing a policy aimed at establishing instream flow needs for the province's rivers and streams. While this approach has been acknowledged and supported in other provinces, it represents a first for Alberta in that it affords a degree of protection for fisheries and other instream uses. But it also raises important legal questions over the rights of existing licence holders who might be deprived of water allocated to instream uses. A similar dilemma faces the Heritage Rivers Program, a federal initiative to preserve rivers of historical, recreational or ecological value. Although several provinces have designated heritage rivers, British Columbia and Alberta have chosen not to participate. Government officials in British Columbia

contend that protection of river corridors would mean changes to present forestry practices which affect watersheds and cause soil erosion. Alberta officials argue that a heritage designation would preclude other current and future uses and that it is in the best interest of the province to manage its water resources for multi-purpose use.

Adapted from *A Primer on Freshwater*, Environment Canada, 1991

Figure 26: *The Canadian Heritage Rivers System*

The impacts of transboundary pollution on ecosystems become magnified when one jurisdiction externalizes its costs by passing wastes onto another. In Canada, institutional responses to transboundary water issues usually take the form of interprovincial or international agreements, and in this regard, the Great Lakes Water Quality Agreements and the Master Agreement on Apportionment between the three prairie provinces have been successful in solving interjurisdictional conflicts.

On the other hand, there are presently no agreements addressing interprovincial pollution and so disputes have been referred to the courts. In one case, Manitoba was forced to close a portion of its fishery because water polluted with mercury had flowed into the province from Ontario and Saskatchewan. Having paid compensation to the fishermen who had lost their livelihood, Manitoba attempted

to sue polluters in the other two provinces to recover its costs. At issue was whether the wrongful act occurred where the licences were issued or where the damage of the fisheries occurred. The Supreme Court of Canada ruled that Manitoba could not hold Ontario and Saskatchewan responsible for licences issued in their jurisdictions. But the Chief Justice and two other judges held that if Manitoba could not interfere with civil rights in Ontario and Saskatchewan, neither could those provinces interfere with the rights of Manitobans to clean water. The Manitoba case suggests that the Canadian courts could provide another mechanism for addressing the externalities problem and resolving water use conflicts within Canadian federalism.

Perhaps the greatest challenge to our institutions is to incorporate constitutional values based on the principle of responsible government. In a democratic country like Canada, it is essential that individuals have a say in decisions that affect their lives. Canadians, unlike their American counterparts, tend to be much more accepting of government decisions and less willing to use litigation as a means of resolving disputes. Yet the potential for a greater degree of citizen involvement in this country exists, especially in the area of environmental rights. Some observers have suggested that Canada needs an Environmental Bill of Rights to ensure citizens the right to a healthy environment. Implicit in such legislation would be the right to sue polluters in civil court and the right to participate in the proposal and review of environmental standards.

The notion of citizen involvement fits well within the framework of sustainable development. By its nature, sustainable development is holistic and inclusive of all interests and therefore requires comprehensive consultation and collective decision-making. Planning for sustainable development, whether at the local, regional, national or international level, brings a wide range of interests to the table, allowing the collective development of strategies that otherwise would be made in isolation. To some extent, the process itself may be more than the outcome, because all parties are involved in exchanging views and determining, by consensus, the course of action that best serves their mutual interests. This is particularly important in resource management endeavours, as both the costs and benefits have ecological and social as well as economic implications.

Greater public participation in sustainable development is the thrust of *Remedial Action Plans* (RAPs) on the Great Lakes. In 1985, the International Joint Commission identified 42 'areas of concern'—17 in Ontario and 25 in the United States. Hamilton Harbour, one of the most polluted in the entire region, topped the list. For years, the harbour was treated as an open sewer, receiving a massive amount of industrial and domestic wastes from the city's two steel plants and municipal sewage treatment facility. Fish which had inhabited the harbour were gone by 1930, and beaches were closed. By the 1960s, the harbour was virtually devoid of aquatic life. Although pollution controls have improved open water quality, and cormorants have made a comeback, the harbour's sediments still contain levels of pesticides, PCBs and heavy metals exceeding government

guidelines. And 118 billion litres of liquid wastes still pour into the harbour every year.

But Hamilton residents are convinced they can undo the damage. In 1986, they formed a 'stakeholders group' made up of representatives from government, industry, environmental groups and community and business organizations to reclaim the harbour, with the goal of making it their city's playground and an attraction for new businesses. It will cost between $120 and $180 million to do this, and no one knows whether the clean-up will be successful. Nevertheless, the stakeholders remain optimistic, and believe that they cannot afford to fail. They are working for not only their city, but for the other Great Lakes communities facing the same struggle to restore waterfronts damaged by years of needless abuse.

Defining a vision for sustainability and sustainable development necessarily includes a re-examination of our relationship with nature. Environmental thought in the past has been directed at fixing the problems created by our rapid industrialization but not the causes, stressing our responsibility for the ecosystem but not our partnership with it. While environmentalism of the 1960s and 1970s made great strides in cleaning up the environment, it did little to erode our perception of separateness, dominance and control over nature. We will also need to break down the cultural, economic and institutional barriers which have stood in the way of human and environmental integration.

When this century began, we had neither the human population nor the technology to modify the earth's life support system. Today we do. And our impacts on the environment are no longer isolated and localized; they are occurring on a global scale and are beginning to threaten the survival of the planet. While the recognition of sustainable development in Canada and other countries is gaining momentum, there is still dispute over which strategies to be adopted. Tougher environmental laws may be unacceptable economically and politically. Attempts at co-operation between levels of governments and among nations may heighten self-interest and jurisdictional autonomy. Traditional antagonists government, industry and environmental groups may have difficulties identifying and working toward common goals. If we are to make any headway, we will have to collectively define those strategies that are equitable, effective and acceptable.

There is always the danger that sustainable development may become just another 'buzzword' in the lexicon of environmentalism unless it is endorsed by all sectors of society—government, industry and the public-at-large. This requires both an understanding of the term's meaning and a recognition of its necessity. This will necessarily involve the adoption of policies and laws which afford a greater degree of protection to the environment, and the expenditure of funds for more environmentally-benign technologies. Some would argue that the cost of sustainable development is too high. But the costs of unsustainable growth have already proven too high.

Sustainable development will also require individual and collective commitment. We are merely stewards of our resources, and the global nature of our problems requires co-operation among all jurisdictions, be they local, regional, national or international. As Canadians, our image as an environmentally-aware people and our technology and scientific expertise will help to bolster our reputation abroad. But we must start at home by re-evaluating the assumptions we have made about water and our individual options for insuring its future.

Ultimately, water is a political issue, and even if we were to commit fully to sustainable development, the factors which have influenced water management in the past won't disappear overnight. To suggest otherwise would be to understate the process of societal change and to ignore our own history. But human history is a story of ingenuity and innovation, of resilience and adaptation. Our challenge now is to reshape ourselves with the same diligence we have, in the past, applied to wresting the future from an 'implacable nature'. Nothing less will ensure our own future, and the future of The Living Flow.

Discussion Questions

1. In your view, do toxic contaminants in the environment pose a significant threat to human health? If so, how might this risk be reduced?

2. Should governments offer industries financial incentives for improving production efficiencies and reducing pollution? Why or why not?

3. The recent Earth Summit brought to light the interrelationship between poverty, development and environment. How might Canada help to improve living standards in developing nations in a manner that is consistent with sustainable development?

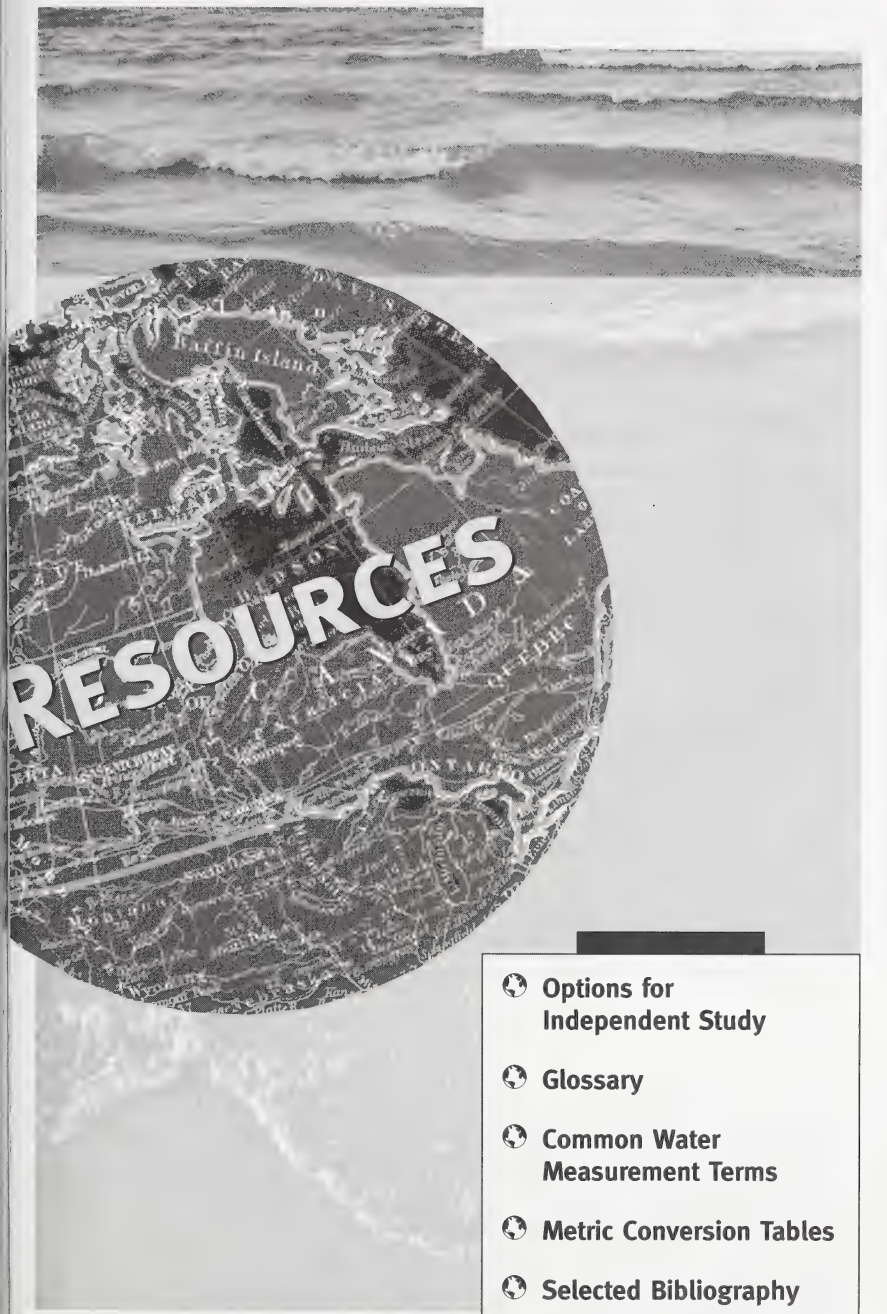
4. Is your current lifestyle compatible with the goal of sustainable resource use? In what ways would you be willing to make changes to help meet this goal?

Recommended Readings

Our Common Future
World Commission on Environment and Development, 1987. *The influential report of the Bruntland Commission and most important resource on sustainable development.*

Water and Free Trade
Wendy Holm (ed.), James Lorimer & Co., 1988. *A collection of important articles on the free trade agreement and its implications for water. This book examines the social and political context of free trade, including long-standing agreements over water between the United States and Canada.*

Cadillac Desert
Marc Reisner, Viking Penguin Inc., 1986. *The story of the American West and the relentless quest to control and allocate its most precious resource—water. Includes a discussion of U.S. water policy and its influence on decision-making.*



- Options for Independent Study
- Glossary
- Common Water Measurement Terms
- Metric Conversion Tables
- Selected Bibliography

Options For Independent Study

1. Attitudinal Survey on Water

In this option you will conduct a survey to measure public attitudes about water. Attitudes are based on beliefs and values and are often expressed as feelings, opinions or behaviours. Questions on any of these will give you a reading of attitudes. The Telecourse gives you many examples from which to choose.

Most attitudinal surveys use a five-point scale, from strongly agree to strongly disagree (the middle value is neutral or no opinion) to measure responses to a series of statements. Survey designers attempt to eliminate survey bias by ensuring that the sample is representative of the population being surveyed and by wording statements so that they are measuring what is intended to be measured. Simple language and unambiguous wording is recommended. Statements should be written to elicit the widest range of attitudes possible.

Your survey should gather demographic information such as age, sex, level of education and occupation so that you can determine if attitudes are related to the background of respondents.

Some examples of survey statements:

a. Human needs for water are more important than non-human needs for water.

b. Canadian laws and regulations are tough enough to adequately protect water quality.

c. Water metering should be mandatory for all municipal users.

d. Industries should be given financial incentives to control pollution.

e. Jobs are more important than environmental protection.

2. Participation in Public Hearing

In this option, you will attend a local public hearing on water policy or water resource development projects and prepare a written position for oral presentation. In preparation for the hearing, obtain and read any background documents or reports prepared by government agencies, consulting firms or other groups. Identify policy options or issues that you feel guide the intent of the hearings.

Your presentation could include the following:

a. an understanding of historical context (the events leading up to the policy review or decision-making)

b. an understanding of hydrologic and/or ecological processes (e.g. river flows, instream assimilation of wastes, fish flow needs)

c. an analysis of costs and benefits

d. a discussion of current policies and water management practices

e. alternatives to existing policy and/or management options.

3. Institutional Analysis

In this option, you will select one of the following areas to review and critique. Your paper should include a discussion of the current practice, its strengths and weaknesses and your recommendations for the future.

a. Legislation governing water allocation and water quality protection (provincial)

b. Water development policy (provincial)

c. Environmental assessment (provincial or federal)

d. Demand management (provincial or federal)

e. Water-related technology

f. Provincial-federal relations in water management

g. U.S.-Canada relations in water management

4. Sustainable Development

In this option, you will evaluate the sustainability of a water-related operation or project in your area using the criteria for sustainable development set forth in the Telecourse.

Your object of study might include the following:

a. current operation of a wastewater treatment plant (municipal or industrial)

b. construction, expansion or upgrading of a wastewater treatment facility

c. installation or expansion of a storm sewer system

d. drainage of agricultural land

e. irrigation development

f. extraction of mineral or fossil fuel resources (coal, oil, natural gas)

g. forestry development

h. road or bridge construction

i. recreation development (e.g. ski hills, parks)

j. thermal or hydro power development

k. industrial development (e.g. petrochemicals, smelters)

l. subdivision development

m. fish and wildlife projects

n. harbour dredging or channelization projects.

Glossary

Acid rain—rain, snow or fog containing emissions of sulphur and nitrogen oxides (wet deposition) and the fallout from dry particulate matter containing these oxides (dry deposition); acid rain is also characterized by having an acidity below pH 5.6

Acute—effect from toxic exposure resulting in rapid disability or death

Acid shock—a rapid lowering of pH due to the melting of acidified snow

Acre-foot—the amount of water covering an acre of land to a depth of one foot (imperial unit)

Aerobic—conditions where free oxygen is present

Alluvial—characterized by sediments contained in flowing water

Ambient water quality—the quality of surface waters; can be influenced by natural or man-made contaminants

Anaerobic—conditions where free oxygen is not present

Aquifer—a water-bearing bed or layer of permeable rock, sand or gravel through which water can percolate; yields water to well or springs

Apportionment—the sharing of water in transboundary rivers

Assimilative capacity—the ability of a waterbody to dilute or absorb substances so that their concentrations are lowered

BAT—best available technology; that treatment technology most effective in controlling pollution

BATEA—best available technology, economically achievable; see *BPT*

Bioaccumulation—the process whereby concentrations of certain toxic substances increase in organisms over time

Biomagnification—the concentration of toxic substances through the food chain

BOD—biochemical oxygen demand; the amount of oxygen in water required to break down organic matter

BPT—best practical technology; the treatment technology in general use financially feasible to implement; known as BATEA (best available technology, economically achievable) in some jurisdictions

Buffering capacity—the capacity of soils and lakes to neutralize acidity

Capillary action—the movement of water over surfaces by forces of adhesion, cohesion and surface tension

Carcinogen—a cancer-causing substance

Catchment area—see *River basin*

Chronic—effect from toxic exposure resulting in long term health problems, such as cancer or birth defects

Coliform bacteria—water quality parameter used to indicate the

presence of disease-causing organisms; measured in terms of total coliform and fecal coliform counts (bacteria originating in the intestinal tract of warm-blooded animals)

Colloid—a substance composed of very small insoluble particles that remain in suspension indefinitely

Consumptive use—a use that diminishes the quantity or quality of water in a river or lake; most withdrawal uses are also consumptive, as they return less water than is withdrawn from the source

Deep well injection—a method of oil recovery in which water is forced into sub-surface formations under pressure; also refers to the disposal of liquid wastes by pumping them into sub-surface formations

Delta—aquatic habitat enriched by the continual deposition of sediments; found at the mouths of large rivers

Demand management—a strategy which advocates managing the demand for water to achieve reduced consumption

Diffuse source—See *Non-point source*

Dilution ratio—the amount of water needed to dilute contaminants in effluent to a desired level in a receiving body

Discharge—wastewater entering a waterbody from a point source

Dissolved solids—solid substances which dissolve in water, such as salts, nutrients and organics

Drought—a condition where soil moisture is depleted (agricultural drought) or water levels are abnormally low (water drought)

Dry deposition—see *Acid rain*

Dryland farming—farming in semi-arid areas that makes use of natural precipitation (as opposed to irrigation)

Diversion—the re-direction of water from a river by means of canal or pipeline

EARP—Environmental Assessment and Review Process (federal)

Eco-nomics—a system of economics, not yet realized, with full integration and accounting of environmental costs and benefits

Ecosystem—a natural system where organisms interact with each other and with the physical environment

Effluent—the liquid product of wastewater treatment

Effluent irrigation—the use of treated sewage for irrigation purposes

EIA—Environmental Impact Assessment; a method employed to identify environmental impacts of a proposed project

Erosion—the removal and transport of sediments by wind or water

Estuary—aquatic habitat characterized by the mixing of salt and fresh water

Eutrophication—enrichment of aquatic systems by the input of nutrients; often results in the increase of aquatic weeds and algae and a lowering of oxygen levels

Evapo-transpiration—see *Transpiration*

Externality—a cost which is passed onto society rather than being factored into production

Flat rate—a charge for water based on a per acre (irrigation) or monthly (residential) assessment

Flow—the volume of water in a river over a period of time, usually measured in cubic feet or cubic metres per second (ft^3/sec or m^3/sec)

Food chain—the order of feeding relationships in an ecosystem

Food web—interconnected food chains in an ecosystem

Free good—environmental resources such as air or water that are deemed to have no intrinsic value

Greenhouse effect—global warming attributed to the increase of certain heat-retaining gases (e.g. carbon dioxide, methane) in the earth's atmosphere

Head—the vertical distance of falling water for the generation of hydroelectricity

Headworks—structures that divert water from a river into an irrigation district

Heavy metals—metals with high atomic weights (mercury, arsenic, selenium, lead)

Hydrogen bonds—weak atomic forces holding water molecules together

Hydrograph—a visual depiction of a river's volume of flow over a specified period of time

Hydrologic cycle—the continued recycling of water by precipitation, evapotranspiration and infiltration

Impact—the social, economic or ecological effects resulting from natural resource development projects

Instream use—the use of water within its watercourse; for example, the generation of hydroelectricity, boating, fishing

Intake—the point at which water is withdrawn from a surface source

Inter-basin transfer—the diversion of water from one river basin to another

Irrigation efficiency—the ratio of crop water requirements to the amount of water diverted for irrigation purposes; expressed as a percentage

Irrigation—the upgrading and/or repair of irrigation rehabilitation infrastructures (e.g. canals, gates)

Irrigation scheduling—the determination of the timing and amount of irrigation based on soil moisture deficits and specific crop water requirements

Leachate—water containing soluble materials filtered from a landfill, dump or mine

LD_{50}—lethal dose; causes the death of 50 per cent of a test organism; used in the determination of toxicity

Licence—a legal document allowing the withdrawal of water or the discharge of substances into a waterbody

LRTAP—long range transport of airborne pollutants (e.g. pesticides, acidic emissions)

Metered rate—a charge for water based on a measured unit volume (cubic metres—m^3—or acre-feet)

Mixing zone—the generally unspecified distance of a receiving stream downstream from a point source wherein concentrations of pollutants are equalized

Mitigation—the moderation or correction of economic, social and/or environmental impacts

Multi-purpose management—the management of water for several uses (e.g. management irrigation, recreation, fish and wildlife)

Natural flow—the flow of a river under 'natural' conditions (i.e. with no storage, diversion or withdrawal)

NOAEL—the no observed adverse effects level of a toxic substance, used in the determination of toxicity. Also referred to as NOEL—No observed effects level

Non-consumptive use—a use that does not diminish the water quantity or quality of a lake or river; most instream uses are also non-consumptive

Non-point source—also *Diffuse source*; a non-specific source of pollution, such as runoff

Nutrients—substances required for growth; usually refers to carbon, phosphorus and nitrogen

Off-stream storage—storage of water by diverting it to a lake or coulee

On-stream storage—storage of water on a river behind a dam

Organochlorines—organic chemicals containing chlorine; includes many substances of concern—DDT, PCBs, CFCs, trihalomethanes, dioxins and furans

Parameter—a factor affecting water quality (e.g. dissolved oxygen, temperature)

Pathogens—disease-causing organisms

Perch basin—also *perched basin*; non-draining pools of water in the floodplain of a delta

Permafrost—a layer of permanently frozen ground underlying much of northern Canada

Persistent—the ability of a toxic substance to resist biological or chemical breakdown

pH—a measurement of acidity and alkalinity based on the relative concentrations of H^+ and OH^- ions in solution

Point source—a specific source of pollution, such as a pipe

Pools—portions of a stream characterized by deep, slowly-moving water

Prior allocation—the principle of allocating water on a first-come, first-served basis

React and cure—the pattern of not dealing with environmental impacts until they have become too severe to be overlooked

Recharge—movement of water through the ground to replenish an aquifer

Recorded flow—the flow of a river measured by gauging stations

Reliable flow—that flow which can be expected nine out of every ten years; may also be referred to as *reliable supply*

Renewable flow—the amount of water in a lake replaced annually by the hydrologic cycle; may also be referred to as *renewable supply*

Retrofitting—in water conservation, the installation of water-efficient devices such as low-flow shower heads

Return flow—the portion of withdrawals that are returned to the source

Riffles—portions of a stream characterized by shallow, rapidly-flowing and highly-oxygenated water

Riparian rights—the right of landholders to use surface water adjacent to their property

River basin—the drainage area or watershed of a river system

Salinization—a process whereby dissolved salts are brought to the surface by the evaporation of soil moisture

Salt water intrusion—contamination of groundwater by the inland movement of sea water

Sedimentation—the settling-out of sediments in a lake or river bed

Sediments—particles of silt, sand and clay; are suspended in water and will eventually settle out

Seepage—the lateral or downward movement of water from an irrigation canal or landfill site

Slough—term used on the prairies to denote water-filled or marshy depressions with no external drainage; on Pacific coast generally denotes a marshy salt-water lagoon

Sludge—the semi-liquid residue of wastewater treatment

Slurry—the mixture of water and extracted ore or bitumen

Soil moisture deficit—a condition where the amount of evapotranspiration exceeds precipitation

Solenetzic—soils with naturally-occurring salts

Solutes—substances dissolved in water

Spill water—excess irrigation water which finds its way to ponds or sloughs

Streamflow—the volume of water passing through a waterway; varies with season and size of watershed

Succession—the replacement of plant species by more mature forms due to changes in light, soil or moisture conditions

Sunsetting—the scheduled withdrawal from production and use of specified materials

Supply management—a strategy aimed at increasing the supply of water to meet increasing demands

Suspended solids—solids which do not dissolve in water and will eventually settle out as sediments

Sustainability—the use of renewable resources in a manner that maintains their long-term regenerative capacity

Sustainable development—development which utilizes resources and the environment in a manner that does not diminish either one

Thermalelectric—the generation of electricity by burning coal or oil

Thermal pollution—pollution from warm-water discharges

Toxics—substances that are harmful to the health of an organism; also called *toxins*

Trace—refers to parts per billion, trillion or quadrillion

Transpiration—water lost through the leaves of plants; also called *evapotranspiration*

Turbidity—cloudiness in water from suspended sediments

Virtual zero—the point at which the presence of a toxic substance is undetectable

Weir—a structure (usually concrete) that raises the level of water in a river or lake; in some native communities, floating logs used in fishing

Wastewater treatment—also called *sewage treatment*; the removal of contaminants from municipal or industrial sewage; classified as *primary*, *secondary* or *tertiary*

Water mining—the removal of water from an aquifer at a rate that exceeds its recharge

Water quality—a relative term, denoting the suitability of water for a given water use

Water quality guideline—also called a *water quality objective*; the concentration of a particular substance deemed to be safe for one or more water uses; non-enforceable

Water quality standard—the enforceable concentration of a particular substance specified in a licence or water quality regulation

Water right—the right to use, divert or store water for a specific purpose; most water rights are granted by licence

Water table—the upper boundary of groundwater deposits

Wet deposition—see *Acid rain*

Wetland—an ecosystem covered by shallow water; wetlands include *bogs, fens, marshes, swamps, sloughs* and *deltas*

Withdrawal—the removal of water from a surface or underground source

Withdrawal—use a use that removes water from a source

Zero discharge—no discharge of contaminants into a receiving body

Zero use—a concept which advocates the elimination of toxic substances by prohibiting their production and use (see *Sunsetting*)

Common Water Measurement Terms

cubic metre—volume of a cube one metre x one metre x one metre; equal to 1,000 litres or 35.3147 cubic feet

cubic decametre—a volume of 1,000 cubic metres or one million litres

cubic feet/second (ft^3/s)—a measurement of river flow

cubic metres/second (m^3/s)—a measurement of river flow

cubic decametres (dam^3)—discharge rate of rivers (total volume); also used to indicate storage volumes

acre-foot—the amount of water that covers one acre of land to a depth of one foot; often used as an irrigation requirement

parts per million (ppm)—a measurement of water quality indicating one part of substance per one million parts water; similarly, ppb (parts per billion), ppt (parts per trillion), ppq (parts per quadrillion)

milligrams per litre (mg/L)—a measurement of water quality; one milligram per litre is the equivalent of one part per million

microgram per gram or kilogram (μg/g or μg/kg)—a measurement of concentrations in human or animal tissues; also used as a guideline for human consumption (e.g. daily intake of 1 μg/kg/day or one microgram per kilogram of body weight per day of PCBs)

Metric Conversion Table

1 hectare = *10,000 square metres*
1 hectare = *2.471 acres*
1 acre = *0.40469 hectares*
1 square mile = *2.59 square kilometres*

1 cubic foot = *6.2321 Imperial gallons*
1 cubic foot = *28.31684 litres*
1 Imperial gallon = *0.16046 cubic feet*
1 Imperial gallon = *4.54609 litres*

1 cubic foot per second = *0.28317 cubic metres per second*
1 cubic metre per second = *35.3147 cubic feet per second*
1 cubic foot per second for one day = *1.9835 acre-feet*

1 acre-foot = *43,560 cubic feet*
1 acre-foot = *1.233 dam*^{3}
1 dam^3 = *.81 acre feet*

1 cubic kilometre of water would fill 300 Olympic swimming pools
(an Olympic swimming pool holds approximately 2.6 million litres)

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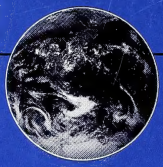
THE Living Flow



Water management decicisions used to be easy: if you needed more water or more electricity you simply built a dam–usually to the fervent applause of the public.

But three decades of the environmental movement–and considerable changing of attitudes towards 'the price of progress'–has shattered that consensus, and made water management one of the more contentious areas of environmental protection.

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Cover photos by Bruce Murphy. Clockwise from upper left: Jack Evans and Kathleen Fry discuss flow management in the Pitt-Addington wildife area, northeast of Vancouver; ACCESS NETWORK cameraman Daron Donahue in southern Alberta with miniature ELMO camera used for boom and underwater shots; a view across the lower Saint John River in New Brunswick; a helicopter flight across Howe Sound to film a pulp mill.

Cover design by Alan Brownoff

ISBN 1-895350-06-9 PRINTED AND BOUND IN CANADA